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COMPOSITE PHOTOGRAPHY.*

BY W. CURTIS TAYLOR.

Composite Photography is the combining of a number of photographic images of similar objects in such a manner as to produce one single image, representing the characteristics of all. In other words, it is a method of getting the average looks of things having a typical relation. The method was first put into practice by Dr. Francis Galton, F.R.S. The aspects of countenance supposed to indicate certain diseases, he expected to represent by this means. He extended the idea in attempting to represent family types, criminal types, etc., conceiving that an average of many individual faces would sink minor differences and preserve the grand peculiarities of their respective classes.

To Mr. Walter R. Furness, of this city, belongs the credit of being the first here to employ this process. This was early in this year, for the copious illustration of a valuable work on Shakespeare portraiture, soon to be issued by Lindsay & Co. Mr. Furness's work is the first in the world, I believe, to use Composite Photography analytically, for the creation of a reliable historic likeness.

* Read before the Franklin Institute, June 17, 1885.

So much for the idea and intention of composite photography. Next, how is it produced?

It is to be supposed that everybody here knows enough of photography to understand that, to produce an effect on the sensitized plate in the camera, capable of being developed afterward into a perfect image, a given exposure, longer or shorter, is required. Then it will readily be conceived that a fraction of this exposure will produce an effect proportionately faint; and that if two or more such effects be caught on the plate, one upon another, the result will be a compound of all; and if the objects were of nearly equal intensity and the separate exposures about the same, no one of these objects would preponderate above another in the combined result. For it must be remembered that the impression, before it is developed, is simply an invisible chemical change wrought on the plate, and is not of the nature of a picture having thickness and density. I make this remark here because some persons have asked whether the last impression made on the negative would not dominate those under it. In this gross sense there is no such thing as "over" or "under" in such an instance.

The exact manner of getting these impressions superposed on the sensitive plate I will now try to show. In the first place the photographs to be combined are all reduced as near as may be to the same size. Those portions which it is most important to fit are brought into juxtaposition by the following means. In the case of human portraits, the line of the eyes is made to correspond with a thread stretched across a light open frame; and the centre of the space between the eyes to correspond with a thread at right angles with the first. These threads are permanently attached to the frame, which also has pierced through it, at its corners, four small holes. A block is provided with four pins agreeing with the holes in the frame. We now take one of the unmounted photographs to be combined, and laying the frame over it so as to make the threads correspond with the eyes in the portrait, we puncture the photograph through the holes in the frame and slip it by means of these holes upon the pins of the block. This is done successively with all the photographs to be copied. If they have been made to scale and carefully wired, the eyes in the whole pile will be very nearly one above another, and the mouths also will match as well as circumstances will admit.

The block with the suspended photographs is now placed before the camera, and each photograph is exposed, in turn, for such a portion of the

whole time as would be required for one good exposure as may be determined by the number of the pictures combined. In the case of the first series of 17, which will now be shown, I think each individual had but 5 seconds. This being but one-seventeenth of the time, it is impossible that any of these men is shown in the composite to be next placed on the screen. But before we remove our friends, we must introduce them. They are the officers of the American Association for the Advancement of Science, for this present year. All but three are from originals we made last summer. You know most of them by reputation. They are:

Profs. Cope, Lesley, Newton, Hilgard, Putnam, James Hall, Langley, Morse, Eaton, N. H. Winchell, Wormley, Thurston, Eddy, Springer, John Trowbridge and Newcomb.

We have in this composite a new man whom the world has never seen; and, from the nature of his make-up, we can criticise him to his face without making any hard feelings. He is a "nice-looking" fellow, but I do not think he looks particularly "smart," as we Americans say. From this composite you will see that the average scientist does not live behind spectacles. The average scientist, also, does not part his hair in the middle. It is true he has a rather giddy shirt front, but that only shows the want of uniformity among his components in the matter of dress. But you ought to hear what some of him say about him.

Prof. Cope, in his sententious way, says he looks "silly." Prof. Thurston says he is "a pretty good-looking fellow." He agrees that he does not look strong in any one direction, but thinks he might do well if he had a powerful incentive, and at any rate has not the narrow look of a specialist. Prof. Morse says: "Your remarks concerning the absence of force in the picture interested me greatly, and I do not see why you are not justified." Prof. Winchell says: "The man you make by mixing us all up seems to have no strong trait of character. He is an average Anglo-Saxon of the nineteenth century, and seems ready, if waked up to it, to take up any business; but he don't look as if he would undertake it without strong impelling circumstances."

On the other hand, a letter from Sir Wm. Thomson, received this week, says: The composite of the "seventeen officers of the A. A. A. S. seems like Prof. ——— (naming one of them). Indeed, when we

first saw it, without noticing it was a composite, we thought it was he."

When we come to consider, later on, the results of composite photography and the limitations of its usefulness, there will be something more to say about the weakening effect of these averages, which I have here only hinted at.

Our next series is not a pleasing one to the eye, but has interest as representing the very opposite of the cast of countenance we have been considering. We are allowed for this purpose the use of some of the portraits from the Rogues Gallery, at Fifth and Chestnut streets. There are four representatives of the ten used in making the composite which is to follow. It did not seem necessary to show the whole of the originals employed. One of these men was a murderer. I think you will have no difficulty in picking him out. The rest were burglars and general thieves.

Looking, now, at the composite from these brutal and mean faces, we shall see that, just as the composite of the wise men did not look so very wise, so that of these vile men does not look quite vile. This new man has an ignorant, stolid, and, as one has said, a "hunted" look, but nothing worse. If, then, it is the case that this averaging process, however entertaining, has limits to its scientific value in one direction, we must look farther to establish its claims to serious consideration. Dr. Galton, himself, says that this process has a beautifying effect upon indifferent-looking human subjects. Just to this extent, then, it fails of useful application.

Why this process should fail of useful application where its subjects are multiform, is not hard to perceive. It is well understood that we can make waves of water and waves of sound interlock so as to produce rest and silence. And thus, if we take away the strong individuality that marks prominence of character, we take away its forcefulness. In our new scientific friend, to use a figure from the phrenologists' lingo, we have a man without bumps. The grand part of one man's head happening over the inferior part of another's has done leveling work; and in these representations the average of the great men is not great, and the average of the vile men is not vile.

But when we work with distinctly marked groups of closely allied objects, then there is no drawback to the scientific and historical value of this method. Such an example you will find in our next series.

Here we have seventeen original and contemporaneous pictures of

Washington; seven being profile views of the face, five three-quarter faces and five midway between these. We are indebted to Mr. W. S. Baker, of this city for the use of these valuable originals, many of which without his kindness would have been practically inaccessible.

The earnest interest attaching to the three Washingtons, the composites now placed before you, has been recognized by the Smithsonian Institution, by the National Army Museum, by two distinguished authors who have published works on Washington portraiture, and by various scientific correspondents.

In looking over these heads of Washington, by fourteen independent artists, you cannot fail to be impressed with the strange diversity among them. Some you would utterly fail to recognize. Yet they are all by careful artists, who must have had reputation at the time, and who testify as eye-witnesses. But how different their testimony!

Now just as in legal investigations we get at the truth by putting together what all the witnesses say, and rejecting the unsupported contrarieties of the individuals among them, so here. What one artist depicted and the others did not, is sunk out of sight, being so faintly shown in the composite. Four-fifths of the photographic exposure is too much for the one-fifth. The burden of the testimony is all against that artist. For example, Stuart's, with its short, bunchy nose, which has long been the popular Washington, should now be discredited. It is not nearly so like the average as Trumbull's; which, indeed, has always been the favorite with a few, but has never been popularized.

It is a remarkable demonstration of the value of this method, so applied, that while the individual Washingtons in each of these three groups bear so little resemblance to each other, their respective composites do represent one and the same man. These composites are now placed side by side, that you may see that each group of artists, *as a group*, tells the same story; and doubtless, as it is the sifting of the testimony of fourteen eye-witnesses, it is a true one.

I consider this remarkable unanimity the crowning feature of these newly created likenesses of the Father of his country; and an earnest of other good things that may be hoped for from this new department of photography.

DISCUSSION.

THE PRESIDENT:—In your remarks about the disagreement among these separate heads of Washington, do you think you kept sufficiently

in mind the years that separated them? Some of these were made about 1779, and others not till 1798. During that time, too, Washington lost his teeth, and that will account for the mouth being different later in life, as in Stuart's.

Mr. TAYLOR:—Yes; but that will not account for Stuart's nose being shorter. And as to age, the earlier pictures shown here do not seem to differ so much in that respect as in the permanent characteristics by which we identify individuals while we make allowance for their advancing years. No doubt the change in the mouth made a marked difference, but I think that would not control our estimate of the face as a whole.

Mr. W. B. COOPER:—Might not a composite be made as well by making a glass positive directly from the negatives?

Mr. TAYLOR:—Yes, just as well; and that is the method of Prof. Pumpelly, of Newport, who has sent me a very fine positive, which I would have exhibited here to-night if permission had been given. But then you fail in that way of getting a negative ready for all manner of multiplication. By the method described here to-night you get your composite once for all, ready to make positives either on glass for the lantern or on paper for more general use.

Mr. G. B. LEE:—Would not the fact of getting the separate pictures from paintings, where the colors falsify the result, account for some of the disagreements among the copies of Washington heads?

Mr. TAYLOR:—It would undoubtedly, if paintings had been used; but all the copies are from engravings, except one of a Houdon which I made directly from the marble bust. If it were necessary to copy paintings, the isochromatic process, described here lately by Mr. Ives, should be used.

Prof. HOUSTON:—I would like to ask Mr. Taylor if there should not be a difference of time in the separate exposures? It seems to me that a photograph or engraving having strong effects should not receive so much time in the copying as a weaker one.

Mr. TAYLOR:—What Prof. Houston says is, in one view, entirely correct, and was a matter of consideration with us in making these composites. Some were tried with the allowance he suggests. But in presenting the subject to scientific bodies I thought it would be better to be able to say that exactly the same time was given to each, as that threw out of the estimate supposable errors of judgment in apportioning the time. I may say, however, that our experiments with time,

with the view named by Prof. Houston, did not materially change the effect.

Mr. ——— :—I notice there is an elongation of the faces in the Washington composites. Why is this?

Mr. TAYLOR:—There is nothing in the process tending to elongate the faces. (After the meeting it was stated that the member making this inquiry sat very much to one side of a line at right angles with the screen, and saw the pictures obliquely. An animated discussion ensued on the relative intellectual indications of long and round heads.)

Mr. WM. TILGHMAN:—Would not the last impression on the plate show itself more strongly than the rest in these composite pictures?

Mr. TAYLOR:—The answer to this very natural inquiry is in the paper I had prepared; but it was probably overlooked in the reading, and I am glad the gentleman has asked it. No, it can make no practical difference, which image goes first or last on the plate, for in any material sense of an image, having thickness, no such thing is produced until the plate be developed. You might place a thousand of these effects—which are nothing but actinic influences—on a plate, and take it from the camera to the dark room, and you would be unable to see anything on the glass except the original film which received the impressions.

THE PRESIDENT:—Did you try different orders of placing these impressions on one another?

Mr. TAYLOR:—Yes; though we were satisfied, by theory, that there should be no difference, we tried it and found none.

MEASURING TEMPERATURES BY THE TELEPHONE.—Dr. Lenz has described in the Bulletin of the St. Petersburg Academy, an ingenious application of the telephone to the measurement of temperatures at a distance. Suppose two stations united by two wires, one of iron, the other of silver, soldered at the two extremities. If the soldering of station M is different from that of station N, a thermo-electric current circulates through the wires. On introducing a telephone and an interrupter into the circuit, the telephone will continue sounding until the observer at one of the stations raises or lowers the temperature of his joint so as to make it identical with that of the joint of the other station; the current then ceases, and the telephone becomes silent.—*Génie Civil; Les Mondes*, Nov. 1, 1884. C.

TRANSPORTATION FACILITIES OF THE PAST AND PRESENT.*

By William Barnet Le Van.

At the December meeting of the Institute I had the honor of reading a paper on "Modern Railroad Facilities," and, from the comments of the press, both at home and abroad, it would appear that certain statements made therein are not generally known or admitted. I therefore propose to present a few leading facts bearing on the subject of this paper, in the order of their occurrence.

CANALS.

Pennsylvania may properly claim the credit of being the mother of the Internal Improvements of the United States, which commenced one hundred years ago.

In the year 1787 authority was asked of the Provincial Legislature for the right to open a water communication between the Schuylkill and Susquehanna rivers, which was granted for what is known as the Union Canal.

In 1791 this work was commenced, and in 1794 one of the western sections, four miles in length, was completed and opened to navigation. From this period the further prosecution of the work was suspended, and it was not again resumed until the year 1816, when a newly organized company assumed its management, under whose direction the canal was completed, and open to traffic in 1824. This is, briefly, the history of the "Union Canal."

It is interesting, and some of my hearers may be amused to know that the origin of the canal system, which has attained such astonishing growth in the United States, can be traced to the little insignificant canal, of about three-fourths of a mile in length, formed by cutting off the bends and deepening the channel of Dock Creek, in Philadelphia. This work, which modern improvements have entirely obliterated, was executed more than one hundred and fifty years ago, *and was the first canal executed in Pennsylvania, or in the Colonies.*†

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* Read at the Stated Meeting of the Franklin Institute, May 20, 1885.

† In connection with the history of the progress of internal improvements in the United States, especially with the development of the means of intercommunication, it may be of interest to reproduce a letter from Dr.

(ROADS) TURNPIKES.

The road leading from Philadelphia to Lancaster, made nearly one

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FRANKLIN to a prominent citizen of Philadelphia. The letter relates to the introduction of canals into the Province of Pennsylvania. It is addressed to S. RHOADS, Esq. (who was Mayor of Philadelphia in the historic year 1776), and is dated London, August 22, 1772. It came to light among some papers of Mr. Rhoads, which passed into the possession of one of his descendants, who is a member of the Franklin Institute, and who has politely permitted this use to be made of it. It is reproduced herewith:

"LONDON, Aug. 22, 1772.

"DEAR FRIEND:—I think I before acknowledg'd your Favour of Feb. 29. I have since received that of May 30. I am glad my Canal Papers were agreeable to you. I fancy Work of that kind is set on foot in America. I think it would be saving Money to engage by a handsome Salary an Engineer from home who has been accustomed to such Business. The many Canals on foot here under different great Masters, are daily raising a number of Pupils in the Art, some of whom may want Employment hereafter, and a single Mistake thro' Inexperience in such important Works, may cost much more than the Expense of Salary to an ingenious young Man already well acquainted with both Principles and Practice. This the Irish have learnt at a dear rate in the first Attempt of their great Canal, and now are endeavouring to get Smeaton to come and rectify their Errors. With regard to your Question, whether it is best to make the Schuylkill a part of the Navigation to the back Country, or whether the Difficulty of that River, subject to all the Inconveniences of Floods, Ice, &c., will not be greater than the Expense of Digging, Locks, &c. I can only say that here they look on the constant Practicability of a Navigation, allowing Boats to pass and repass at all Times and Seasons, without Hindrance, to be a Point of the greatest Importance, and therefore they seldom or ever use a River where it can be avoided. Locks in Rivers are subject to many more Accidents than those in still water Canals; and the Carrying away a few Locks by Freshet or Ice, not only creates a great Expense, but interrupts Business for a long time till Repairs are made, which may soon be destroyed again, and thus the Carrying on a Course of Business by such a Navigation be discouraged, as subject to frequent Interruptions. The Toll, too, must be higher to pay for such Repairs. Rivers are ungovernable Things, especially in Hilly Countries. Canals are quiet and very manageable. Therefore they are often carried on here by the Sides of Rivers, only on Ground above the Reach of Floods, no other Use being made of the Rivers than to supply occasionally the waste of water in the Canals.

"I warmly wish Success to every Attempt for Improvement of our dear Country, and am with sincere Esteem,

"Yours most affectionately,

"B. FRANKLIN."

"I congratulate you on the Change of our American Minister. The present has more favourable Disposition towards us than his Predecessor."

"*To S. Rhoads, Esq.*"

hundred years ago (about 1792), was the first turnpike in the United States; whilst the old bridges over the Schuylkill, near Philadelphia (which have given place to the noblest structures of the kind in America), were the first structures erected for the passage of rivers in our country. At the present day, Pennsylvania is unrivalled in the number, the magnitude, and the boldness of design of her bridges.

RAILROADS.

Railroads, also, were first introduced in Pennsylvania. In September, 1809, the first experimental track in the United States was laid out by John Thompson, Esq. (the father of John Edgar Thompson, who was afterward the President of the Pennsylvania Railroad Company), civil engineer, of Delaware county, Pa., and constructed, under his direction, by Sumerville, a Scotch millwright, for Thomas Leiper, of Philadelphia. It was sixty yards (180 feet) in length, and graded an inch and a half to the yard. The gauge was four feet, and the sleepers eight feet apart.

The experiment with a loaded car was so successful that Leiper, in the same year, caused the first practical railroad in the United States to be constructed for the transportation of stone from his quarries, on Crum creek, to his landing on Ridley creek, in Delaware county, Pa., a distance of about one mile. It continued in use for nineteen years. Some of the original foundations, consisting of rock in which holes were drilled and afterwards plugged with wood to receive the spikes for holding the sleepers in place, may be seen to this day.

In 1811, a charter was granted to the Union Canal Company by the Legislature of Pennsylvania, authorizing the company to construct railroads as appendages to that work. On the 31st of March, 1823, a law was passed authorizing Col. John Stevens, Horace Binney, Stephen Girard, and others who have since become distinguished, to construct a railroad from Philadelphia to the Susquehanna. Surveys were promptly executed by the parties named, but they proved to be defective. The delay in obtaining subscriptions for this unprecedented enterprise (*the first of the kind which was ever projected in any part of the world, and the first which was ever authorized by the law in the United States*), induce the friends of this work to apply to the Legislature for certain alterations in the Act of Assembly. On April 7th, 1826, the Act of 1823 was annulled, and a new Act passed authorizing the formation of a new company; and on the 24th of March,

1828, this railroad was made a State work, and is now known as the Pennsylvania Railroad.

In 1816 the first railroad on which self-acting inclined planes were erected was executed by Mr. Boggs on the Kiskeminetas river, in Indiana county.

On the 27th of March, 1824, the Legislature of Pennsylvania passed an Act "providing for the appointment of a board of commissioners for the purpose of promoting the internal improvements of the State." Within four days thereafter, the Governor appointed Jacob Holgate, James Clarke and Charles Treziyulney, who met and effected an organization at Lebanon, on the 16th of April, when they adopted a resolution "to employ an engineer of known talents, skill and experience in canaling, if such an one could be found, and submit to him the organization of such other aid or assistance as he should find necessary."

On May 10th the Board met at Philadelphia, and the President reported "that he had made the most diligent search and anxious inquiry after an engineer who was experienced in constructing canals, and that all his efforts to procure such an one had been unavailing." An attempt was then made to obtain the services of an engineer from the United States corps, but, after some time spent in correspondence, this also failed, and the Board, being left to their own resources, employed surveyors to run levels, and took hold of the work themselves, displaying great energy and perseverance.

After mentioning the fact of having purchased a spirit-level, and ordering four more, the Board in their report proceeded as follows: "When the Commonwealth has the proper instruments, young men will be found who will very soon learn to use them with accuracy and dispatch, and in this way the fruitless effort to get assistance from abroad will be superseded by the culture and encouragement of genius at home. We have found, by observation and experience, that, purchasing the proper instruments, and encouraging active men who have some general acquaintance with science to use them, is the most effectual method for the State to get a proper corps of civil engineers, and to have the most and best work done, in the shortest time and at the least expenses." It is hard to realize at this day that such difficulties in procuring engineers existed at so recent a period; and when we take into view the immense extent of our present railroad and canal systems, we can scarcely believe it to be the growth of fifty years; nor,

when we consider the manner in which engineers were manufactured, should we be surprised that mistakes were made, but rather wonder that so few important errors were committed.

The Mauch Chunk railroad was the third to be finished and put in operation. It was made entirely of wood and worked by gravity. This road commenced at the coal mines which are, in fact, in the valley of the Little Schuylkill, on the Panther Creek, a short distance below the summit of "Mauch Chunk," or "Mountain of Bears." It is used for the purpose of carrying the Schuylkill coal from this valley to the top of the mountain, and thence to the Lehigh river; hence, the common, but erroneous name of this coal, in the market, is Lehigh coal. The road was commenced in the winter of 1826–1827, and was finished in four months. The extent of the main line, which is single, is nine miles, and the branches and side lines extend in the aggregate three and three-quarter miles. This was the first railroad of any considerable extent made in the United States. This road was run with mules, which were walked on the outside of the track to protect the sleepers from wearing; and, the road having considerable descent one way, the cars ran down of themselves. A low car was provided similar to a "gondola" car, and taken with the train; and on that part of the road where the cars ran themselves by gravity, the mules were made to mount the platform of the low car and were *carried down with the load;* and it was astonishing how soon the mules became accustomed to, and fond of this diversion.

On one occasion, the car on which the mules ride down the plane (of about seven miles in length), broke loose, and descended without its passengers (mules), and it became necessary to send for it; the mules, however, with characteristic firmness, refused to be driven down for the purpose of bringing it back. Persuasions, threats, and even the *ultima ratio* of drivers—the logic of the cowskin—could not induce these favored quadrupeds to waive their usual privileges, and to submit to the degrading employment of drawing, in lieu of their pastime of riding, which they had come to look upon as a vested right. Their drivers were actually obliged to change lots with them, and harnessing themselves to the car, to drag it up to the malcontents, who triumphantly took possession of it, and resumed their wonted cheerfulness.

This railroad is better known to fame as the "Switch-back," which has been traveled with such rare gratification by tens of thousands.

From the above, it will be seen that railroads of any description

were first introduced in Pennsylvania; whereas, hitherto, Massachusetts has been given the credit of precedence in this respect.

The fourth railroad was built at Quincy, Massachusetts, by Gridley Bryant, in 1827. This road, which is known as the "Granite railroad," was designed and built by those interested in getting material for the Bunker Hill monument from the granite quarries of Quincy.

The gauge of this road was five feet, and the rails consisted of pine 12 inches deep, covered with oak plank, and protected by flat iron bars. The wooden rails were laid upon granite sleepers 7½ feet long and spaced 8 feet apart. The road had a considerable incline from the quarries towards the landing-place on the Neponset river, and a single horse drew immense loads over the rails. From the wharf the granite blocks were towed around the harbor of Boston by a steam tow-boat and landed at Charlestown. In 1871 this road ceased to exist, being purchased by the Old Colony Railroad.

The Bunker Hill Monument is a granite obelisk 221 feet high, and now marks the scene of the important struggle on Breed's Hill at the beginning of the Revolutionary War. General Lafayette laid the corner-stone, June 17th, 1825, and Daniel Webster delivered one of his most memorable orations on the occasion. The Monument was completed in 1842, and was dedicated June 17, 1843, in presence of John Tyler, President of the United States, and his Cabinet; Daniel Webster being, as before, the orator of the occasion.

STEAM POWER APPLIED TO RAILROADS.

More than eighty years ago, Oliver Evans, of Philadelphia, discovered the hitherto unsuspected value of railroads, and published to the world that their merits had been unappreciated, their properties misunderstood, and their capacity for extended usefulness undeveloped. He earnestly maintained that they ought not to be confined to limited districts as the mere auxiliaries, or inferior substitutes, to canals; that they were, in fact, greatly superior to the latter for the purposes of general commerce, and on the most extended lines. In these just, and now popular opinions, he stood alone, holding them not the less indubitable because they originated with himself. No human being, at that time, either in Europe or elsewhere, had ever dreamed that railroads were adapted to the transportation of passengers or merchandise, or that they could be usefully extended beyond a length of a few miles.

The idea of employing steam, as a means of propelling carriages, is well

known to be almost coeval with the invention of the steam engine; but no mode of effecting this had ever been tried, or even suggested, unless the mere project of Watt (which, with great deference be it mentioned, is now acknowledged to be utterly impracticable), which was never even attempted, be considered as an exception. Oliver Evans, who had never heard of steam being applied to this purpose, was early impressed with its importance, and commenced his celebrated experiments in 1784, and finished his first engine in 1801. Poverty compelled him to sell it to be used for another purpose. He immediately commenced another engine and carriage, and in the latter part of the winter of 1803–1804 he propelled it by steam through the streets of Philadelphia, in the presence of more than 20,000 astonished and hitherto incredulous spectators, who came with the expectation of seeing a failure.

No railroads then existed in America to test the capacity of this rude but primitive locomotive steam engine. A temporary railway (the first ever attempted in America) was employed to prevent the wheels sinking into the ruts or inequalities, on *part only* of the road traversed. This was the humble origin of that wonderful machine which was destined to revolutionize commercial intercourse by land. The plans and numerous drawings of Mr. Evans were sent to Europe, by his agent, and exhibited to many persons; his suggestions were copied without acknowledgement, and others reaped the benefit of his discoveries.

The superiority of railroads to canals, even when *horses* were employed on both, was zealously maintained by Evans before it had been imagined in Europe or this country, and their greater superiority, when locomotive engines should be adopted, was repeatedly pressed on the public attention. He endeavored, without success, to urge the building of a road from Philadelphia to Pittsburg, and several years after, a railroad from Philadelphia to New York. In the last-named project he offered to take stock to the amount of $25,000, but he was in advance of the age in which he lived. His projects were regarded as visionary, although to-day we are whirled over railroads between the two cities in two hours, and every traveler on them should bear in grateful remembrance the name of Oliver Evans; a man whose projects have been accomplished, and whose predictions have been fulfilled to the letter, although a straight-jacket was voted to him formerly, almost by acclamation, as the reward of his genius. Fitch, who con-

structed the first steamboat at Philadelphia in the year 1787, and Fulton, of Pennsylvania, who successfully introduced steam navigation, likewise had poverty and ingratitude meeded to them as the reward of their exertions.

In the early period of railroad history in the United States, the practice was a lighter construction of the permanent way than was adopted in England. This, no doubt, has materially aided the remarkable extension of railroad lines over so great an area of country. The rails of our early railroads were composed of flat iron bars (strap-rail) attached to wooden string-pieces, 6 x 10 inches, supported on cross-ties similar to those of our present street railroads. The weight of the locomotive, concentrated upon four wheels with a narrow wheel-base, was entirely too much for such a substructure. The roadway soon became uneven, and travel over it was both uncomfortable and dangerous. To the last, the writer can bear testimony. Over thirty years ago he had occasion to make quite a number of trips between New York and Easton, Pa., on the New Jersey Central Railroad (which at that time extended from Elizabethport to Plainfield, New Jersey). Several times on these trips, the end of the rail turned upward and pierced the bottom of the car in close proximity to his person. In railroad parlance these were called "snake heads," and they were often the cause of fatal accidents. On some of the early railroads wooden piles and tressles were first introduced as a substitute both for sleepers and embankments — notably, the South Carolina railroad and the Carbondale and Honsedale (Horatio Allen, chief engineer). The superstructure was composed of flat bars attached to wooden string-pieces (6 x 10 inches), supported generally on piles; the latter were secured by ties. The piles were driven to a great depth in some of the marshes which the road crossed, and in other parts of the work they formed a substitute for embankments.

STEAM ENGINE.

The production of the steam engine is undoubtedly one of the greatest triumphs of modern science; whether we consider the vastness of its power, so far excelling any mechanical contrivance which, previous to its invention, had been discovered or even thought of; or whether we regard this protean agent with respect to its application to the arts, manufactures or transportation by sea and land. In our own day, through the genius of Watt and Evans, and the inventive talents

of other engineers, the steam engine has become stupendous alike for its force and its flexibility, for its prodigious power as well as for the ease, precision and ductility with which such power can be varied, distributed and applied. Our improved steam engine has increased indefinitely the mass of human comforts and enjoyments, and rendered cheap and accessible, all over the world, the materials of wealth and prosperity. It has armed the feeble hand of man, in short, with a power to which no limits can be assigned, completed the dominion of mind over the most refractory qualities of matter, and laid a sure foundation for all those miracles of mechanical power which are to aid and reward the labors of after generations.

But not one of the uses to which steam power has been applied exceeds, in extent and importance, its application to *locomotion*, connecting, as it does, the most distant points' and promoting that facility of intercourse which, of all improvements is the greatest; since, by bringing the different parts of a country together, its strength is increased, and that unity of action and intelligence secured, which brings all, even the most remote and widely scattered districts, into the way of improvement, both moral and mental.

It was an important era in the history of civilization when, about eighty years ago, steam was first applied to navigation. The remarkable facilities which this application afforded to trade and general intercourse, and the great change it has actually effected, and is still effecting, in our commercial and social relations with other countries, are appreciated by all. Previous to this discovery, navigation was impeded, and its utility vastly curtailed, by the uncertain and often opposing action of wind and waves, which often made a voyage of a few miles a matter of toil, uncertainty and delay. Rivers and other great inlets of the sea were of little or no advantage to commerce, and the grand benefits which we generally associate with the very name of *river* were then scarcely known, because no craft could ply constantly on any of the great streams, when they could proceed with certainty in one direction only. As an illustration: In early times on the Mississippi, which flows at the rate of five or six miles an hour, it was the practice of a certain class of boatmen, who brought down the produce of the interior to New Orleans, to break up their boats, sell the timber, and then return home slowly by land; and a voyage up the river, from New Orleans to Pittsburgh, a distance of about 2,000 miles, could hardly be accomplished, with the most laborious efforts,

within a period of four months. Now the above journey is easily performed in about three days.

LOCOMOTIVES.

During the summer of 1829, a small experimental locomotive, built by Peter Cooper, of New York, was successfully tried on the Baltimore and Ohio Railroad, at Baltimore, making 13 miles in less than an hour, and moving, at some points on the road, at the rate of 18 miles an hour. One carriage, carrying 36 passengers, was attached. This was considered a working model; but, what was most important, he demonstrated that it could run at a high rate of speed round curves of a short radius.

Mr. Cooper made the above experiment at the *same time* that Robert Stephenson's locomotive, the "Rocket," was run on the Manchester and Liverpool Railway, in England.

Ross Winans, writing of the trial of the Cooper locomotive, makes a comparison with the work done by Stephenson's "Rocket," and claims a decided superiority for the former. He concluded that the trial established fully the practicability of using locomotives on the Baltimore and Ohio road at high speeds, and on all its curves and heavy gradients without inconvenience or danger.

To show the disadvantage Mr. Cooper labored under, he was unable to find such tubes as he needed for his boiler, and was compelled to use gun barrels. The whole machine weighed less than a ton.

It is a rather curious coincidence that both Oliver Evans and Peter Cooper were coach-builders or wheelwrights by trade.

The fact is, that applying the steam engine to locomotion was regarded as a much smaller mechanical feat in America than it was in England. The representative steam engine in Britain, at the time railways were first started, was the heavy, slow-moving condensing engine of Watt. Radical changes were necessary to convert that engine into a locomotive. America, on the other hand, had the high-pressure, high-speed engine, invented by Oliver Evans, and it was well adapted for land transportation purposes without change of type.

While the directors of the Liverpool and Manchester Railway, in England, were disputing about what system of operation to adopt, the majority favoring stationary engines and rope traction, the directors of the Baltimore and Ohio and the Charleston and Hamburg Railroad,

of South Carolina, unanimously decided to operate their railroads with locomotives, and gave their general managers directions to have locomotives built.

The Gartner & Davis locomotives, that did the first regular service on the Baltimore and Ohio Railroad, were constructed after the style of the Cooper locomotive.

On the THEORY of the FINANCE of LUBRICATION, And on the VALUATION of LUBRICANTS By CONSUMERS.

By Robert H. Thurston, Hoboken, N. J.

(Concluded from page 45.)

The variation of friction with pressure, above alluded to, is illustrated by the following values of the coefficient of friction, as obtained by the writer, the journal being of steel, in good order, the bearing of bronze—gun metal—working at a speed of rubbing of 150 feet per minute, and running barely warm to the hand, conditions common in practice.

Friction at Varying Pressures.

Oils.	Pressure: lbs. per sq. inch; kgs. per sq. cm.							
	4 0·3	10 0·7	25 1·8	150 10·5	200 14·1	250 17·5	300 21·1	500 35·2
Sperm	0·12	0·08	0·04	0·01	0·01	0·01	0·005	0·003
Lard	.....	.....	0·06	0·014	0·013	0·011	0·006	0·004
W. Va.	.....	.....	.....	0·012	0·009	0·008	0·005	.....
Grease	.....	.....	.....	0·025	0·020	0·015	0·012	0·011

The journal was lubricated, in the usual way, by means of an oil cup, the oil feeding down by a wick. As the cup was kept full, the supply was very free, and the figures are probably good for the case taken. These figures may be doubled by the selection of an unguent ill adapted to the work, and may be increased to almost any extent by abrasion and cutting. On the other hand, they may be decreased at least one-half by freer supply.

The amount of lubricating materials used in cotton mills has been investigated by Mr. Edward Atkinson, who finds that, in fifty-five mills, working on similar fabrics, and among which a variation of 20 per cent. should not have been expected, the actual range was 350 per per cent. Subsequently, careful management reduced the average from $10.03 to $6.67 per 10,000 pounds of cloth made. Another and still more important effect of this investigation, and the publication of its results, was the expulsion from that market of inferior and dangerous oils. The oils found in use, and tested, varied in quality to the extent of 300 per cent. The best oils for these mills were reported by Mr. Woodbury as being mineral oils mixed with some sperm or lard, and having a gravity of about 28 to 32 Beaumé (S. G. 0·886 to 0·864).*

The total power used in these mills is found by Mr. Henthorn to average about 0·75 horse-power per loom, or 15·75 horse-power per 1,000 spindles, and to vary from 0·5 to nearly one horse-power per loom, or from 11 to 22 horse-power per 1,000 spindles. The same authority finds the power demanded by engine and shafting alone to form from 17 to 34 per cent. of the whole. The smaller of these figures represents the best practice, the higher figures show what may be expected with faulty arrangement and bad lubrication. The quantity of cloth made in New England mills, according to data furnished the writer, mainly through Messrs. Hoadley and Woodbury, ranges from about 2,000 pounds per annum, per horse-power, up to above 3,500. A variation of temperature, such as occurs between winter and summer, causes a variation of ten per cent. in the production of cloth, the greater amount being obtained in summer. A mill making print, cloths, 64 threads to the inch, and of No. 32 yarn, with frame warp and mule filling, produces about one pound of cloth per spindle per week, and demands about 16 horse-power per 1,000 spindles. Thus 10,000 pounds of cloth per annum requires 200 spindles, and proportional plant, costing about, at present prices, or a little above, $11 per spindle for all machinery and buildings, exclusive of stock, land, and live capital, and the power demanded is not far from 3·3 horse-power. A New England mill, well known to the writer, contains 44,752 spindles, makes 7,800,000 yards of cloth per year, weighing 1,240,000 pounds, the mill running 3,000 hours per annum, using 625 horse-power, and consuming 700 gallons of sperm and 2,900 gallons of min-

* Transactions of the American Soc. Mech. Engineers, vol. iv, p. 319.

eral spindle oil per year. The sperm oil cost, at last reports, $1.22 per gallon, and the spindle oil 25 cents. Another large mill, near Boston, working 55,000 spindles, makes, annually, about 3,000,000 pounds of cloth, requiring 1,300 horse-power, and using oil costing $1,300 per year. A 37-set woolen mill makes 750,000 pounds of cloth and uses 300 horse-power.

On the whole, it may be said that the quantity of oil used in cotton mills varies from 10 to 30 gallons per 10,000 pounds of cloth made per annum, averaging not far from two gallons per horse-power per annum, and costing from 20 cents to $1 per gallon, averaging probably not far from 50 cents.

A machine shop uses, properly, a much heavier oil than a cotton mill, and much less in proportion to power employed. One of the largest and best-known steam engine building establishments in the country uses 120 horse-power, and consumes 350 gallons of sperm oil for the heaviest machinery, such as planers, and for the wood-working tools, 100 gallons of finest heavy mineral engine oil for the engine, 300 gallons of mineral or mixed oil, at about 40 cents per gallon, for shafting and tools, and expends a total, on lubrication, of about $600 per year, an average of about 80 cents per gallon. Another and smaller shop, also well known to the writer, employs but 30 horse-power, and uses 175 gallons of oil per year for lubrication, the average cost being but 18 cents per gallon. Still another establishment, building tools and light machinery, uses an estimated amount of 100 horse-power and 700 gallons of oil at 20 cents per gallon, and for grease used on the main line of shafting, 25 cents per pound. A similar shop of somewhat larger size, reports to the writer an expenditure of but 40 gallons per year on 550 bearings, the oil being supplied by hand, a certain number of drops at a time, at regular intervals. Probably a fair estimate for the heavy class of machinery found in such establisments may be about 0·0002 gallons per horse-power per hour.

The Lowell Pumping Engine, designed by Mr. Leavitt, uses about 0·00015 gallons per horse-power per hour, a very low consumption for that class of machinery.

Railway work is probably more exacting in its demands, and more variable in its practice, in regard to quantity of oil used, than any other class of machinery consuming lubricants. Its character is such that it should be comparatively easy to select the best lubricant for the case; and yet there is probably no class of machinery on which a wider range

of quality and price of oil is to be found in use. The trade in oils for this work is in a singularly unsatisfactory state; and no system is generally practiced by which to determine precisely which oils are best for the purpose. Consequently, the losses due to mistakes in selection, and in the use, of oils are often of enormous magnitude. In no direction is a definite method of test, purchase, and use of lubricants more desirable than in this.

The consumption of oil is usually reckoned per train-mile, and the following are the figures given by one of the best of the Massachusetts roads for one month on the engines alone:

	Coal—Lbs. per mile.	Oil—Gallons.
Best Express Engines	43	0·009
Best Freight Engines	55	0·0094
Average Passenger Engines	50	0·009
Average Freight Engines	61	0·0084

The Boston and Albany Railroad, in November, 1884, reported the following:

Cost of fuel per mile	$0·179
Cost of lubricants per mile	·0052
Cost of repairs per mile	·0441
Total	$0·2283
Miles run per ton of coal	39·18
Miles per quart of oil	28·93

On the Boston and Maine road, the cost of fuel is given at about ten cents per train-mile, that of oil about one-half cent. The average of all Massachusetts roads in one year, as given to the writer, was for wages on the engine, $0·28, for fuel, $0·115, and for oil and waste, $0·0105. On the Pennsylvania Railway, between New York and Pittsburg, in 1883, the totals were reported as follows:

Total mileage	15,625,478
Coal, tons of 2,000 lbs.	743,020
Wood, cords	13,685
Oil, quarts	613,478
Tallow, lbs.	721,992
Waste, lbs.	267,158
Tons moved one mile	2,996,893

The coal averaged in price but $1.00 per ton, exclusive of freight

charges to the road, the wood cost $2.88 per cord, the oil 28 cents per gallon, the tallow and waste, each 8 cents per pound.

The New York, Lake Erie and Western Railway reports for December, 1884, as follows:

Performance of Locomotives.

AVERAGE, MONTH OF DECEMBER, 1884.

Length of Road.....563 Miles.
Total No. Locomotives, 241. No. making Mileage, 205.
Miles run per Locomotive.....2474·30
No. of Cars per Trip—Passenger 5·0, Loaded Freight..... 18·9
Percentage of Empty Freight Cars of all hauled..... 14·4
5 Empty Freight Cars rated at 3 Loaded.

MILES RUN TO

1 Ton of Coal by Locomotives 20·46, by Cars hauled..... 332·21
1 Pt. Lub. Oil and T. by Locomotives 13·55 " ..... 179·90
Lbs. Waste used per 100 miles..... 0·32

COST, ETC., PER MILE.

		Loco. Mile.	Car Mile.
Fuel used	pds.	95·36	7·19
Cost of Fuel	cts.	6·16	0·47
" Oil, Tallow and Waste	"	0·52	0·03
" Repairs	"	4·02	0·26
" Loco. Furniture and Fixtures	"	0·13	0·01
" Wages Engineman and Fireman	"	6·34	0·39
" Repairers and Cleaners	"	1·01	0·06
Total Cost		18·18	1·22

Cost of Wood per Cord, $2.74. Coal per ton, $1.25.
Time table mileage allowed and 5 m. per hour for Terminal Switch.

COST PER MILE, ETC., FOR

Repairs of Passenger Cars, 0·53 cts. Repair of Freight Cars, 0·25 cts.
Lub. Oil, Pass. Train Cars, 0·06 " Freight Train Cars, 0·01 "
Miles per Pt. " " 56·56 " " 210·32 "

The cost of wear of journals and of bearings does not appear, as a separate item, in the preceding statistics of railway economy; but, as already stated, it is often a very serious expense. It has been found that, in some instances, the average wear is about one pound of journal for each 75,000 miles run, and the same weight of bearing for each 25,000 miles. Could the lubrication be made as perfect and the dust be excluded as thoroughly as in indoor work, the wear would be reduced

to a fraction of one per cent. of these amounts, and would become insignificant. In one case reported to the writer, it was found that the cost of oil, for 100 cars moved 100 miles, was about $1.00, that of power $8.00, and the expense for wear of journals and bearing was $5.00 nearly. The estimate for cost of power is perhaps rather low. This remarkable case was observed where the lubricant was "black oil." The tendency of this oil to produce injury of surfaces was called to the attention of the writer, some years ago, by a well-known railroad superintendent, who sent him samples of staybolt-rods whose threads had been cut, one with lard, and the other with black, oil. The first was as smooth as could be desired; the second was rough, ragged on the edges of the thread, and in places the thread was completely stripped. No difference had been made in cutting except in the choice of the oils.

The cost of steam-power, which is usually the principal item included in the cost of the wasted work of friction, varies greatly with size and kind of engine, character of fuel, expenses of operation, and with all the items, such as insurance, repairs and depreciation, incidental to its use. A fair figure is, perhaps, for ordinary mill-engines of moderate power, $0.02 per horse-power per hour, and double this amount is not unusual. Of this total, from 50 to 80 per cent. may be assumed to be, on the average, the cost of fuel. Adding the incidental costs, it may be considered a fair estimate, for such cases, to take the total charge at $0.03 per horse-power and per hour. As the values of all items of expense, in every case, in practice, will be determined by direct experiment* and by observation, it is unnecessary to enter into this division of the subject very minutely, when, as here, only illustration of the principles developed is proposed.

The actual cost of steam-power in mills ranges from as low as $50 to as high as $100 per horse-power, according to circumstances. The latter figure represents the cost of the best modern machinery. The interest on first cost may be assumed at 6 per cent., the appropriation for a sinking fund at 2½ per cent., the working expenses at not far from 10 per cent., in good cases, and the cost for fuel, on the average, at about 20 per cent. of the cost of the plant. The total cost, thus calculated, will vary from, perhaps, $35 to nearly, or quite, $100 per annum, per horse-power. It has been taken, above, at $60, and about

* "On the several Efficiencies of the Steam Engine," Trans. Am. Soc. Mech. Engrs., Vol. III, p. 245, Journal of the Franklin Institute, May, 1882, Art. XIII.

fifty per cent. of its own amount added for miscellaneous costs not included in the direct calculation.*

In illustration of the application of these principles, the following cases, which are examples of practice falling within the experience of the writer, may be given:

(1.) In a machine-shop using about 100 horse-power, of which one-half is supposed to be applied to the overcoming of the friction of lubricated surfaces of journals and their bearings, it is found that the cost of power is very nearly $100 per horse-power per annum, inclusive of all of the incidentals above mentioned. The average coefficient of friction is not far from 0·05; the oil used costs, on the average, $0.50 per gallon, consisting mainly of lard, and heavy mineral oils, and is supplied at the rate of 0·02 gallons per working hour, the working year consisting of 3,000 hours.

Then, if 50 horse-power should be used in the work of overcoming fractional resistances, the cost of power would be $5,000 per annum, or $1.67 per hour, which is represented, in the equations already given, by $b\,f_1$. Since f_1 is found to be 0·05 b is equal to 33·333. The oil used being found to cost, in place on the journal, $0.50 per gallon, and to be used at the rate of 0·02 gallon per hour, the total cost of lubrication is $0.01 per hour. Hence we have (Eq. 4):

$$K_1 = k_1 q_1 + b\,f_1 = 0{\cdot}01 + 1{\cdot}67 = \$1.68 \qquad (A)$$

or $5,040 per annum.

Should it be proposed to make a change of oil, using oil costing but $0.25 per gallon, and of which 0·03 gallon per hour will be demanded, and which will make the coefficient of friction 0·06, the cost of power will be increased one-fifth, and that of oil diminished one-fourth; the equation then reads:

$$K_2 = 0{\cdot}25 \times 0{\cdot}03 + 33{\cdot}333 \times 0{\cdot}06 = \$2{\cdot}0075 \qquad (B)$$

equal to $6,022 per annum.

The gain effected in cost of oil is one-fourth of one cent per hour; while the loss, in cost of wasted power, is 33·333 cents per hour. In other words, a gain of $7.50 per annum on the books of the purchasing agent, or proprietor, is to be charged against a loss, in the cost of

† For details of such estimates, see the papers and reports of Messrs. J. C. Hoadley and C. E. Emery, especially on the Watuppa Reservoir Case, and estimates presented to the American Society of Civil Engineers.

running the establishment, of $1,000. The net loss is $982.50 per annum.

Should it prove possible to adopt a system of oil-baths, or other method of free lubrication, so as to bring down the coefficient to 0·02, as is not at all unlikely to prove practicable, and assuming that four times as much oil, of the second quality, is used as in the last case, we shall have

$$K_2' = 0{\cdot}03 + 0{\cdot}666 = \$0.696 \text{ per hour}, \qquad (C)$$

$2·088 per year, producing a gain of two-thirds the total cost of lost work, as in the last case. This amounts to nearly $4,000 per year, or, as compared with the present running expense, as given in the first case, to nearly $3,000. The annual cost of oil, in the three cases, amounts to $30, $22.50 and $90, respectively, and it is at once seen that, in this example of application, the saving, actual or possible, to be effected by any bargain made in the oil market, is absolutely insignificant in comparison with that to be produced in the shop by careful lubrication. A system of collection and purification of the oil running off the journals into the drip-pans may, in nearly all cases, be easily adopted, which will at once reduce the cost of lubricant, and make its first cost a matter of still less consequence.

Finally, suppose a grease used in this shop, such as now costs 25 cents per pound, and assume that it is given as a sample, costing the proprietor nothing, but bringing up the coefficient of friction, as an average, to 0·10: The cost of power is now the total expense, and this becomes

$$\$3.333 \text{ per hour}, \qquad (D)$$

or $10,000 per annum; while the loss to the owners of the establishment, on their bargain, is $5,000 per annum.

It will next be asked: What price represents the limit which may not be exceeded, without loss, in the purchase of the oils proposed to be substituted for that first used in this instance? This question is answered by the application of the criterion established by equations (10) and (14). Thus, comparing cases (A) and (B), we have

$$k_2 = \frac{k_1 q_1 - b(f_2 - f_1)}{q_2} = \frac{0{\cdot}01 - 0.333}{0{\cdot}03} = -\$10.78.$$

The second oil causes a loss of $10.78 for every gallon used, and, hence, cannot be used without loss, unless the user is paid that sum to take it and apply it to his machinery.

Comparing cases (A) and (C), using equation (10),

$$k_2 = \frac{0{\cdot}01 + 1{\cdot}00}{1{\cdot}2} = \$0.84\,;$$

and it is found that the second disposition of the poorer grade of oil is of such advantage that it is as well worth $0.84 per gallon as is the better oil worth $0.50, used as at first proposed, and as is customary. But it would be a still better investment, in all probability to purchase the better oil, and to use as in the case compared.

Comparing cases (A) and (D), using equal amounts, per gallon,

$$k_2 = \frac{0{\cdot}00 - 33{\cdot}333 \times 0{\cdot}05}{0{\cdot}02} = -\$83.44\,;$$

and the heavier lubricant is found to subject the user to an expense amounting to over $10 for each pound used. It must not, however, be from this inferred that it is always wasteful to use the greases. They are often advantageous, where exceptional pressures are used or troublesome bearings are met with, and are sometimes absolutely indispensable, saving large amounts by their reduction of expenses in the cooling and preservation of journals and renewal of bearings. In the above case, it is probable that a much smaller quantity of grease than of oil would have sufficed, which would have reduced the total cost of grease, if purchased, but would have proportionally increased the loss to the proprietor, both absolutely and as reckoned per pound of unguent applied.

(2). As a second illustration, assume a cotton mill to use a good oil, averaging $0.70 per gallon, at the rate of 0·7 gallon per hour, with a mean coefficient of friction 0·10 on machinery demanding 400 horse-power, of which 120 horse-power is required to overcome the friction of surfaces lubricated by the oil. Taking the value of the power at $65 per horse-power per annum, and 3,000 working hours, we have $b = \$26$. If it is proposed to substitute for the oils used in this mill others averaging a cost of $0.40 per gallon, giving a mean coefficient of friction of $f = 0{\cdot}12$, and of which one gallon will be used per hour, we shall have

$$K_1 = 0{\cdot}49 + 2{\cdot}60 = \$3.09,$$
$$K_2 = 0{\cdot}40 + 3{\cdot}12 = \$3.52,$$

and a gain of 9 cents per hour, or $270 per annum, in buying oil, is to be set against a loss of 52 cents per hour, or $1,560 per year, in

increased expenses on the account of operating the mill, the net loss amounting to above one thousand dollars a year. Had the coefficient of friction been increased to a greater extent, the loss would have been correspondingly greater. The differences among the lubricants sold for mill purposes in the market are sometimes enormously greater than assumed above, and a loss of $10 per horse-power, annually, is probably not an unknown case, and this is equivalent to about double that sum per horse-power expended on the friction simply.

Applying the criterion to this case, we have

$$k_2 = \frac{0{\cdot}49 - 0{\cdot}52}{1{\cdot}0} = -\$0.03,$$

as the loss on each gallon of the second lubricant. The owner of the mill cannot afford to accept it, in substitution for the better oil, as a gift. The substitution of an engine-oil, on the spindles, for the best spindle-oil, might readily double the expenditure of power absorbed by the spinning machinery, and thus increase the cost of both lubrication and power, the former having both a higher co-efficient of friction and greater price than the latter.

(3.) In further illustration, assume a railway train to be supplied with a good standard lubricating oil for engines and axles, costing, on the journal, $0·25 per gallon, and to use 0·02 gallon per train-mile, the co-efficient of friction, when everything is in good order and all journals cool, being 0·01. Taking as a fair figure, $0·10 per mile for costs of power and incidentals variable with power, and presuming that, under the circumstances, wear may be reduced to an unimportant amount, and may be neglected, the relative costs of lubricating material and of power may be introduced into equations (18) and (19), as in the above examples. We thus obtain

$$K_1 = k_1 q_1 + df_1 = 0{\cdot}005 + 0{\cdot}10 = \$0{\cdot}10\tfrac{1}{2},$$

as the total money-loss due to the existence of friction.

If it be proposed to substitute for the oil in use a cheaper oil, costing, on the journal, $0·15, and of which fifty per cent. more will be used, and which will give a coefficient of friction 0·015—a not uncommon case—the total cost becomes

$$K_2 = 0{\cdot}15 \times 0{\cdot}03 + 10 \times 0{\cdot}015 = \$0{\cdot}15\tfrac{1}{2};$$

and it is found that a gain of one-twentieth of a cent, per mile, in cost of oil, is met by a loss of one hundred times as much, or five cents

per mile, in cost of power. Should the second oil increase wear, its cost must be added to the account of losses produced by the change. Had the second oil been used in the same quantity as the first, one and a half cents per mile would have been saved, over the last figures, and the loss would be then $3\frac{1}{2}$ cents per mile.

To determine what could be paid for the second oil, as used, in order that no loss should take place in consequence of the change, equation (17) is to be used, and this gives

$$k_2 = \frac{0{\cdot}005 - 10 \times 0{\cdot}0005}{0{\cdot}03} = \$0{\cdot}00;$$

that is to say, the real value of the oil to the consumer is just 0, if the oil at first used was worth 25 cents a gallon. In many instances, in every-day practice, losses occur many times as great as those just estimated.

The conclusions to be drawn from the principles and the theory which have been presented in this paper, and from the examples of application to practice which have been introduced as fairly representing their use in various departments of engineering, are obvius and definite:

(1.) To secure the highest possible efficiency of machinery, and maximum economy in the operation of establishments in which it is employed, lubricants must be very carefully selected with reference to the precise conditions, as to pressure, velocity of rubbing, etc., met with in the individual case.

Where, as in machine-shops and mills, for example, there exist great differences in these respects, it will be found advantageous to use different oils; as heavy oils on the engine-bearings, special "cylinder oils" in the steam cylinder, lighter oils on the shafting, and the lightest of the better classes of lubricating oils on light machinery, as on spindles.

(2.) Differences in price of oils, or other lubricants, are usually of exceedingly slight importance in comparison with differences in costs of power; and the value of the coefficient of friction is, therefore, of vastly greater consequence than either the price of the unguent or its endurance.

(3.) The best oils for specified purposes should be taken, as a rule, whatever their market price; while the oils which are not well adapted to the purpose in view cannot be economically purchased at any price.

It will often be found that the best quality of oil is not necessarily the best oil for any one specified purpose. An oil may be intrinsically excellent, and may be a very expensive oil, but may, nevertheless, be absolutely worthless for the purpose in view. A good engine-oil would, for example, be quite unfitted for use as a spindle-oil, and, though several times as high in price, might be the cause of such considerable waste of power on light mill-machinery that the mill-owner, as has already been seen, might find it to his interest to decline using it, even if it were offered him as a gift. The heavy oils are the most costly, and, in this case, the better oil is, therefore, also the cheaper in the market.

(4.) The cost of using a lubricant which is not well adapted to the work is so great that unguents should always be tested, and their adaptability to the special case determined, by a correct system of chemical and physical tests, and by trial upon a good testing-machine, if possible, under the exact conditions of the intended use.

The determination of the quality of any lubricant is an easy task; but the identification of the real conditions of use, as proposed, may sometimes be difficult. The difficulty arises, however, not from faults of method of test or uncertainty of results, but from defects of design or construction, or sometimes of management, of the machinery upon which it is proposed to use the oil. Where journals are kept in good order, and are properly proportioned, no difficulty need ever arise in the attempt to find the best possible lubricant for them. As a rule, there is no excuse for a condition of machinery which gives rise to such uncertainties. As a rule, in all successfully conducted departments of business, such uncertainties do not exist; they do not arise with sufficient frequency to invalidate the above rules. Testing-machines are now made in sufficient variety of form and of ample range of application, and of such satisfactory accuracy, that there is no longer necessity of accepting the risks, and of meeting the enormous expense, involved in the application of lubricants of unknown quality to valuable machinery.

(5.) Where lubricants of the precise quality desired are not found in the market, it is advisable to secure the right grade by mixing. This can always be done by making a series of mixtures of good oils, such that, at the one side, the gravity and other qualities shall be too high, and, on the other side, too low, for the special application had in view, and thus working out—after determining by trial the law of

variation—the mixture most perfectly suited to the purpose. The writer has often been called upon thus to determine the best of a series of mixtures for a cylinder-oil, for example, or for an engine or a spindle-oil. By this method he has sometimes improved the quality of an oil for a special kind of work more than one hundred per cent. Satisfactory results can almost invariably be attained by careful and skillful work.

CRYSTALLIZATION.*

By Dr. Persifor Frazer.

Ladies and Gentlemen:—We find in nature two classes of phenomena: changes in the act of taking place, and actual existences which are the results of changes which have taken place; or, to speak more accurately, changes proceeding so rapidly that we can note them, and others so slowly that they seem to us to be states of equilibrium. It is rarely, if ever, that phenomena are due to one cause unmodified by others. When not the outcome of the operation of a single cause, the phenomenon in question is a resultant analogous to that explained in mechanics by the diagram of forces, and as such may be made to show the relative force of each cause. Such resultant phenomena are least frequently produced by few and nearly equal causes, and when so, they evince this by their simplicity whether geometrical or other. More frequently they are the effects of many unequal and unlike causes and constitute objects which all the efforts of science thus far have not sufficed to unravel completely.

Among the phenomena of which the creating forces have been comparatively few and like, are those curious and beautiful objects known as crystals, to which it is intended to devote your attention this evening.

It has been said that when the forces acting simultaneously upon a body were comparatively few and similar, the resultant forces were usually simple. Observe the lines of the figure made when a mass of fragments is piled up and allowed to find that state of rest which results from the combined gravitation of the earth and the resistance

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* A Lecture delivered at the International Electrical Exhibition, Tuesday, October 7, 1884.

of the particles to compression. One sees these lines in the dump piles of our great ore mines and furnaces, in the piles of debris which crumble and fall from vertical cliffs; and indeed in every grocer's shop when sugar or coffee is scooped from the bins and piled on the scales. The attraction of gravitation tends to carry all the particles straight to the centre of the earth, but there being the resistance of the matter which interposes, the particles jostle each other and fall sideways in all directions. [*Illustrations of talus were projected on the screen.*]

The same kind of phenomenon, but from different causes, is seen in stalactites. Here the drop of liquid tends to fall, but the attraction of cohesion constantly increasing through the evaporation of the solution and the consequent crowding together of the solid substance which it contains, the drop is arrested in its path; and finally the cohesive force triumphs and the stalactite is made by so much the larger. The manner in which this building takes place can be seen by observing any stalactite.

Sometimes these same forces applied differently give rise to a different result, as for instance, in the mineral springs, which in overflowing at the surface, evaporate and leave incrustations which build up circular walls unlike those of the stalactite or stalagmite. The forms which these openings assume are dependent upon the strength of the solution, the nature of the salt, the force of the spring, and the rapidity of evaporation; and all of these are factors in the resulting form, though all functions of the same simple pair of causes. [*A photograph of one of the Yellowstone Geysers was projected on the screen.*]

Symmetrical form is not only produced by building, but also by destroying; and analogously to the art which hews out of the block of marble the beautiful statue, so the forces of nature; the wind, the frost and the rain, with the aid of gravitation, chisel out of solid sandstone beds forms of symmetry often of great beauty, as for instance, in the "Garden of the Gods," in Colorado, and elsewhere. [*Photographs of various forms of which were thrown on the screen.*]

Other symmetrical forms, oftentimes closely resembling crystals, are formed by the rapidly cooling lavas or molten streams which force their way upward to the earth's surface when in the act of congelation the constituent molecules seeking room for themselves press their fellows in all directions and in turn are pressed by them. The columns thus formed are quite uniformly five-sided. [*Projections of the Basalt, of the Giant's Causeway.*]

The above symmetrical forms are the results of various simple forces acting simultaneously on matter, but none of them are forms of crystallization as usually understood; and a better definition of this latter is now necessary.

It will be observed that the above forms have been impressed upon the passive matter which exhibits them, by extraneous forces. The matter has merely been the plastic material to receive impressions from outside forces correlated to its essential character. But in crystallization the case is reversed. The matter assumes form from a centre or centres *within* its own mass in all directions *through* its own mass. By virtue of what power?

The answer to this question is virtually my reason for appearing before you this evening, for the managers of this lecture course have very wisely requested their lecturers to confine themselves as much as possible to subjects germane to the Exhibition which is now proceeding here; that is, of Electricity in some of its forms of manifestation, and one of these forms has been long known to be magnetism. The force which impels the minute particles of a crystallizing body to so arrange themselves, the one upon the other, that a symmetrical form results, has been finally traced by the master scouts in the army of original investigators in Nature's domain, to intimate connection (if not identity) with that mysterious attraction of the loadstone for iron; and this attraction will here properly become the subject of a short consideration

[*A magnetic needle was here projected on the screen by means of the vertical lantern.*]

This familiar instrument needs no explanation to this audience so far as regards its simpler manifestations (though, did time permit, many wonderful things about it and the manner of its action might be profitably said).* In my hand I hold a thin slab of steel in the condition of a magnet, and you observe that one end attracts, and the other repels a given end of the needle while the middle of the bar acts indifferently towards it. If the bar be broken at this point of indifference the two ends thus formed instantly change their action. Instead of indifference one end strongly attracts and the other as strongly repels a given end of the needle, while the opposite extremities of the fragments to which these ends respectively belong have the opposite action. But now the middle

* It is hardly necessary to explain to the readers of these lines that this manner of presenting the subject was first adopted by Prof Tyndall.

point of each of these fragments is indifferent. Breaking each of them again the same apparently marvelous accession of energy is noticeable, and so on as far as mechanical means permit us to sub-divide matter. Each of the minutest fragments exhibits the same qualities just observed in the larger pieces, *i. e.*, with reference to a given pole of a magnetic needle attraction at one end, repulsion at the other end and indifference in the portion—first called by Faraday in a sort of grave scientific pun—the "equatorial zone." Note, however, the following facts. So long as the magnetic force exercised by every particle on its neighbor is approximately equal to that exercised by either end of the large unbroken bar, the effect of sub-division is not merely to separate but to increase the polar force relatively to the equatorial indifference. For, when the bar is broken in two, each of the halves will divide into fragments of two poles and one equator midway between them. The result of successive divisions will be to continually diminish the zone of indifference relatively to the regions of magnetic force, and the effect of this, in a state of extreme comminution, as if the middle zone of these minute magnets disappeared and left simply the attraction and repulsion of their opposite extremities. This is an important aid to understanding the final arrangement of these little particles by their mutual attractions and repulsions.

This will be illustrated to you in a moment, but before thus making the experiment let us recapitulate that: by every subdivision of the parent magnet (following our experiment), the polar activities are increased in the proportion of 2 in the original bar, 4 after the first break, 8 after the second, 16 after the third, and so on: whereas the number of different zones is increased only from 1 in the original to 2 after the first break, 4 after the second, and 8 after the third, etc.

Thus the number of seats of action and the activity of action, as the masses grow smaller, increase; while the seats of neutral or balanced activity become narrower. These facts are also important to bear in mind when one seeks to understand the marvelous rapidity and immense force manifested by the phenomena which are the subjects of this lecture.

It will be shown that the one pole of the same bar seems to repel poles like itself of other bars and to attract those different from itself. What then would be the effect if a large number of little magnets were scattered between two large ones?

[*Iron filings were here sifted upon a plate of glass resting on the condenser of the vertical lantern, and this covered by a second plate. The north ends of two bar magnets were then placed on the second plate. Afterwards the opposite poles of the bar magnets were substituted.*]

In both of these series of curves the direction is due first to the paramount attraction of the large centres for each particle of the iron filings as a whole; and second to the repulsion from each other of similar parts in the adjacent little magnetized particles, which are, each, a little magnet.

The great Faraday pondered these lines of force deeply and started a series of investigations which are not yet complete but which have already led to interesting results.

Brugmans, Le Bailliff, Seebeck and Becquerel had already been at work on the subject before 1846. Weber, Œrsted, Reich, Plücker, Tyndall and Knoblauch, all contributed largely to the research, but the results, important as they are, cannot be considered here except as to one particular.

Faraday had divided all bodies examined by him into paramagnetic and diamagnetic, *i. e.*, those which arranged themselves (1) in a line joining the opposite poles of a strong magnet, or (2) in a line perpendicular to this. Of the first class iron was the type; of the second, bismuth. So far as these results apply to crystals they must now be prefaced by a few words on the structure of these beautiful bodies. [*Combinations of prisms and pyramids thrown on the screen.*]

For the sake of convenience, all crystals have been divided into forms belonging to seven systems, called crystallographic systems, but these seven systems are not necessary for the mathematical study of the phenomenon, although they render the study easier of classification.

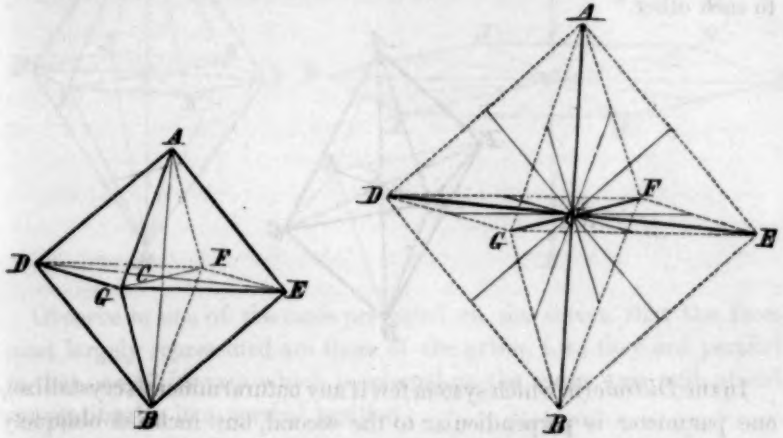
For the sake of simplicity, the *central point* of a crystal (an arbitrary point, only definable in crystals or solids which are symmetrical) is assumed as the point where certain arbitrarily chosen straight lines intersect. Usually these straight lines or co-ordinate *axes* are restricted to three, but in one case (again for a mere convenience) they are increased to four. With this explanation, they may be rapidly sketched.

The seven crystal systems are divided into the orthometric systems, or those in which the axes make, with each other, only right angles, and the klinometric systems where they make one or more oblique angles.

Those portions of the "main axes" which are wholly enclosed within the crystals are called parameters, and the shape of the whole

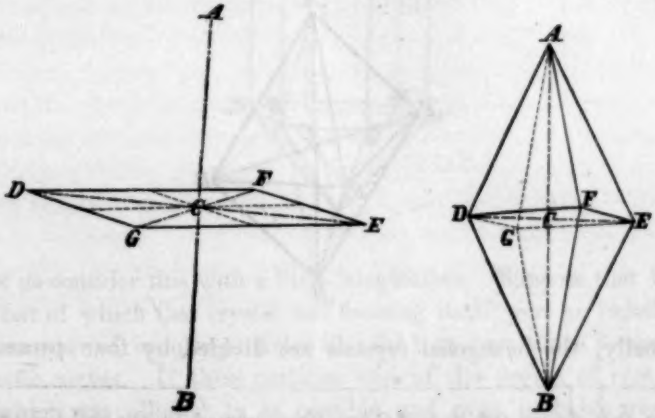
crystal is determined by the relative lengths of the parameters—the latter being the distance from the centre of the crystal along every axis to the intersection of that axis with some part of the surface of the crystal.

The first of the systems is the *Isometric*, in which the three axes are equal and perpendicular each to each.



[The lines *A B*, *D E*, and *F G*, are the three principal axes ; the first or the *main* axis is always supposed vertical, and the others are the *subordinate* axes.]

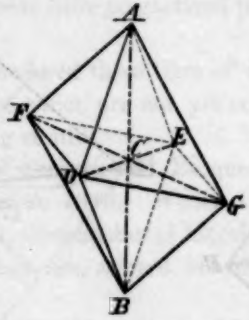
The next is the *Tetragonal*, of which the parameters are perpendicular each to the other. But two of them are equal in length, and these two longer or shorter than the third.



[The letters in this and the succeeding diagrams correspond with the analogous points in that of the isometric pyramid.]

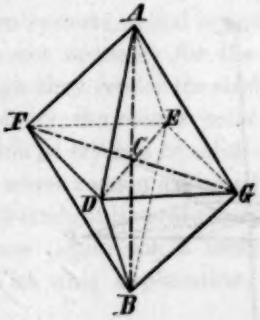
In the *Rhombic* system, all three axes are perpendicular each to each, but no two of them are of the same length. These constitute all the orthometric systems. [*See last diagram of which imagine the two axes in the horizontal plane to be of different lengths.*]

The first of the klinometric systems is the *Monoclinic*. One axis is perpendicular to the other two, which, latter, are inclined obliquely to each other.*



In the *Diclinic* (in which system few if any natural minerals crystallize), one parameter is perpendicular to the second, but inclined obliquely to the third; while the second and third are inclined obliquely to each other.

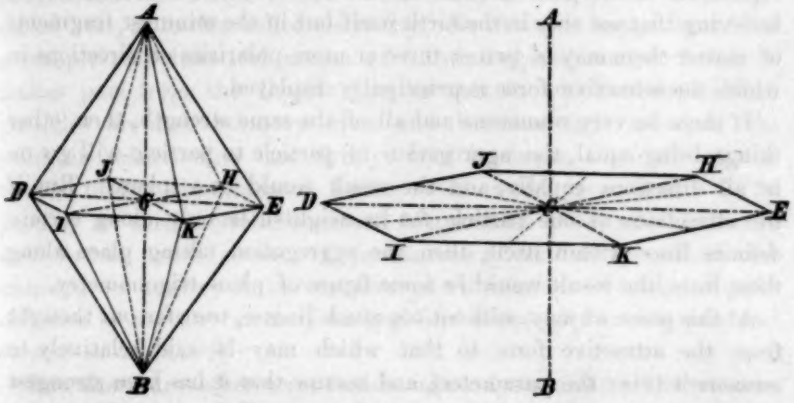
In the *Triclinic*, each parameter is oblique to, and of a different length from every other.



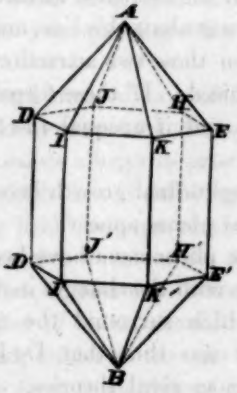
Finally, the hexagonal crystals are divided by four parameters;

* In this figure the line *F G* has been turned to the right in order to show the shape of the pyramid better.

three in the same plane intersecting each other at angles of 60° and the fourth perpendicular to them.



Observe in one of the cases presented on the screen that the faces most largely represented are those of the prism, *i. e.*, they are parallel to that one of its axes which is selected as the *main* axis and placed conventionally in a vertical position.



Let us consider this with a little imagination. Suppose that in the fluid out of which that crystal was forming itself were an indefinitely large number of minute particles like the iron dust which formed the magnetic curves. If these particles were of the degree of comminution which was alluded to as possible and even probable when the division of matter was carried beyond the range of sense, the equato-

rial region of the particle would be practically abolished, and the particle would be left free to rotate according to the attractions or repulsions of its poles alone. But there is the best of reason for believing that not only in the earth itself but in the minutest fragments of matter there may be two or three or more polarities or directions in which the attractive force is principally displayed.

If these be very numerous and all of the same strength, then, other things being equal, the aggregation of particle to particle will go on in all directions equally, and the result would be a sphere. But if the attractions of one particle for its neighbor be only along certain definite lines within itself, then, the aggregation taking place along these lines, the result would be some figure of plane trigonometry.

At this point we may, without too much license, transfer our thought from the attractive force to that which may be said relatively to measure it (viz: the parameter), and assume that it has been strongest along those parameters which are the longest. Take our prism truncated by pyramidal (and sometimes afterwards by basal planes.)

May we not assume that (so far as each individual crystal was concerned) the *growth force* was greatest along the main axis, and that though growing in all directions, it grew most rapidly in the direction of this axis, at least, until the increased attraction along the other axes impeded the building power along this line, and that its actual direction was the resultant between these two attractions. At such a time the pyramid planes are produced. If these forces remain equal the result will be the 45° pyramid, and, if unequal, the flattened pyramid, or the acute pyramid.

Finally, when the longitudinal growth becomes indefinitely weaker than the lateral, the basal planes appear.

The causes of all these phenomena have been connected by some of the best minds of the day with the changes in direction and intensity of currents of electricity which surround the molecules and even the atoms of all bodies. It was thus that De la Rive sought to accommodate to each other various rival theories.

That electricity, and especially its form of manifestation, magnetism, has much to do with both locking and unlocking the bonds which hold solids together is manifest from many experiments, and in none more than in those usually grouped under the head of electrolysis, or the separation of chemical compounds into their constituents by the electric current.

These phenomena, however, cannot be confounded with those just spoken of as affecting the ultimate molecules and atoms, until it be proven that the result is not due as much to the phase of energy called heat, as to that called electricity. Be that as it may, I have here a simple and beautiful means of illustrating the manner in which bodies pass from the liquid state (or that in which their smallest particles are free to move upon and between each other) to the solid, in which they are firmly held in forms that tell of the nature of the simultaneous forces which acted upon them. [*The poles of an electric circuit immersed in a solution of sugar of lead were here thrown on the screen. Crystallization of lead on the cathode was observed on passing the current through the solution. On changing the direction of the current the fronds of lead dissolved from one pole and formed on the other.*]

But there are other ways besides electrolysis to show this remarkable tendency to systematic arrangement; this building up of crystals before the eyes of the observer; and one of these ways is by evaporation.

When the magma or vehicle in which the minute particles are held is diminished, and the distance between these little masses is decreased, a point is finally reached when their mutual attractions act definitely and permanently, and the consequent architecture is dependent upon their relative force.

Some of these actions lend themselves readily to lecture illustration, while others are controlled by many circumstances not perfectly understood, and therefore impossible always to provide for. The first experiment of this kind to which I will call your attention is one where the mineral thus building itself belongs to the isometric system; but though the absolute attractive force in the crystals of this system is equal in the three directions, it does not follow that at one time, one, and at another time, another of them, should not manifest itself more forcibly as has been hinted, might be the case when the crystal architecture changes from one form to another of the same system. This is apparent in the present case, and the result is a series of fronds apparently like the ice crystals on the window pane of a frosty morning, but in reality when analyzed quite different from them. [*Sal ammoniac was here allowed to evaporate on a glass plate in front of the lantern.*]

Thus the power *temporarily* to manifest a greater growth force along

one parameter than the others makes it possible to have a great variety of *forms* in one crystal *system*.

Compare, for instance, these double pyramids (or octohedra) of arsenious acid which, though so different, belong to the same or isometric system.

The salt now forming is chlorate of potassium which crystallizes in the monoclinic system, but it is not so easy to prove this to an audience.

I shall not attempt here to go into the explanation of this apparatus designed to render these phenomena visible to you, but will simply say that I employ polarized light, which, while unchanged by passage through minerals belonging to the isometric system, is rendered visible, as color, by traversing minerals of all the other systems in certain directions.

[*Sodium bi-tartrate, copper sulphate and mica were used to intercept polarized beams*]

This last experiment brings us to an important fact, by reason of its application to organic bodies. We have seen how light is modified when passing through bodies which have attractive forces greater in one direction than in another during the time of their formation. It could be shown that a plain piece of glass, which in its normal state exercises no influence on polarized light, instantly does so when put to unequal strain in different directions. With the explanations of this fact we have not here to do, but it is enough for our present purpose, that it is a fact. Now, all organic bodies polarize light under proper conditions, and this we have just seen is because all organic bodies are subjected to strains varying in the degree of their force with the directions through the body. But this is tantamount to saying that all organic bodies are the result of that architecture due to polar forces.

Wherein, then, lies the difference between the crystalline architecture of the so-called inanimate nature and that of the highly organized beings which we endow with certain qualities which we deny to other equal masses of matter? It is true that the question is not settled by this resemblance or analogy between the two great kingdoms of nature, but it adds simplicity to the conception of the universe if we may regard all matter as different expressions of one matter, and all force as different modes of one force.

MEANS FOR EXTINGUISHING FIRE.*

By C. John Hexamer.

INTRODUCTION.

Before we can enter into a discussion and description of how to command the phenomena of combustion we must understand a few preliminary facts. If we rapidly draw our hand through the surrounding space, we feel a certain amount of resistance. This resistance is due to a gaseous body which surrounds us on all sides, and which we term air, a substance known to the ancients, who tried to weigh it. Aristotle, for example, filled a bladder and weighed it, then exhausted the air and reweighed the bladder, and actually believed he had thereby determined the weight of the atmosphere. It was not, however, until the advent of the experimental era under Galileo and Torricelli that its weight or pressure was determined. It was found at the level of the sea, to be about fifteen pounds to the square inch.

This surrounding fluid consists of two gases, oxygen and nitrogen; not, however, chemically combined, but merely mixed in the proportion—in round numbers—of seventy-nine parts of nitrogen and twenty-one of oxygen. Nitrogen, which is fourteen times heavier (atomic weight) than hydrogen, is a gas entirely negative in its qualities; it does not support combustion, and its purpose in the air is merely to act as a diluting agent so as to make the effects of oxygen less active. Oxygen, the great supporter of life and also the great destroyer in nature, is an odorless, colorless gas, sixteen times (15·95 atomic weight) as heavy as hydrogen. It and its combinations constitute the greater part of our earth. The so called crystalline rocks which consist largely of silicates, contain from forty-four to forty-eight per cent. of oxygen. Water, which is a compound of oxygen and hydrogen, contains one part by weight of hygrogen to eight of oxygen. It is this element which causes all those phenomena which we ordinarily term combustion. Phenomena which it causes while ordinarily diluted with nitrogen (air) are greatly intensified when the element is pure; and even metals, such as iron and steel, when ignited in a globe filled with oxygen, burn with brilliant scintillations.

We are now ready for the question, "What is combustion?" I

* A lecture delivered before the Franklin Institute, January 9, 1885.

would define it as a chemical union of oxygen with some other element or elements, accompanied by an evolution of light and heat, while similar unions of other substances, not with oxygen directly, I will term "chemical combination." Substances which unite with oxygen are termed combustible substances, while oxygen is a supporter of combustion. These terms, although but relatively correct,—as combustion might be defined as an act of a chemical union accompanied by an evolution of light and heat—are for our purposes very convenient and will be retained throughout.

We must, before entering into the subject under discussion, understand what is meant by the temperature of ignition, or the ignition point. It has been found that before a substance can ignite (take fire) either in the air or oxygen, a certain temperature must be reached, and this necessary temperature is termed the ignition point or temperature of ignition. While for some substances this point is very low, for others it is extremely high; for example, nitrogen will only unite with oxygen at the intense heat of the electric spark; while phosphorus burns slowly at 10°C. (50°F.), as may be noticed in the dark (phosphorescence), it does not burn brightly until heated to 60°C. (140°F.), and zinc ethyl and phosphuretted hydrogen ignite in the air at the ordinary temperature.

But most bodies do not unite with the oxygen of the air rapidly enough at ordinary temperatures to produce light and heat, but must be heated for a production of active cumbustion. In the case of the decay of organic matter or the rusting of metals oxidation goes on slowly, producing heat, and the total amount of heat that a decaying log produces in the long time required for its destruction is exactly equal to the amount of heat produced by its rapid oxidation (burning) in a stove. We, therefore, distinguish between quick and slow combustion.

The temperatures of different flames vary greatly. Bunsen found that the temperature of the flame of hydrogen burning in air is 2,024°C., temperature of a hydrogen flame burning in oxygen 2,841°C., carbonic oxide 1,997° when burning in air, and 3,003°C. when burning in oxygen.

In order to measure the quantity or strength of a material or force, we must have a measure or standard of comparison. The standard for the measurement of heat, if the expression be allowed, as heat is a force and not a material, is the "thermal unit.," the amount of heat required to raise the temperature of one cubic centimetre of water one

degree Centigrade. This measure is now almost universally employed by scientists, although the old English caloric unit, the amount of heat required to raise one pound of water one degree Fahrenheit, is yet sometimes employed. Two other units are also used; in Germany, the amount of heat required to raise one kilogramme of water one degree Centigrade is much used; while the unit of one pound of water to one degree Centigrade is sometimes employed.

COMBUSTION IN OXYGEN.

One gramme of	Thermal units.	Observer.
Charcoal	7,273	Lavoisier.
"	7,167	Dulong.
"	7,912	Depretz.
"	7,714	Grassi.
"	8,080	Favre and Silbermann.
"	7,900	Andrews.
Diamond	7,770	Favre and Silbermann.
Natural graphite	7,811	" "
Gas carbon	8,047	" "
Hydrogen	34,462	" "
"	33,808	Andrews.
"	34,180	Thomsen.
Sulphur	2,220	Favre and Silbermann.
"	2,307	Andrews.
Phosphorus	5,747	"
Zinc	1,301	"
Iron	1,576	"
Tin	1,233	"
Copper	602	"
Marsh gas	13,063	Favre and Silbermann.
"	13,108	Andrews.
"	13,120	Thomsen.
Olefiant gas	11,858	Favre and Silbermann.
"	11,942	Andrews.
"	11,957	Thomsen.
Carbon monoxide	2,431	Andrews.
"	2,403	Favre and Silbermann.
"	2,385	Thomsen.

Numerous experiments, made by different scientists, have proved beyond a doubt that a constant quantity of heat is given off when the same weight of the same substance burns to form the same products of combustion, whether the combustion proceeds slowly or rapidly. Numerous measurements of the amount of heat disengaged by the combination of different substances with oxygen have been made, of which those of Andrews, Favre, Julius Thomsen and Silbermann are the most correct. The above table compiled by Roscoe, shows the heat of combustion in thermal units for one gramme of substance burnt.

WATER.

Water was the first material employed to extinguish fire. One of the best materials and means for extinguishing fire are well-filled galvanized iron water-buckets. These should have conical bottoms, so that they can not be used for other purposes than that for which they are intended. They should be kept filled at all times. A very good method of keeping them filled is to appoint a special man for this purpose, and fine him one dollar for every bucket which is found empty. It should be the particular duty of the watchman to examine the buckets daily and report on their condition; and, in order to increase his surveillance, the money obtained for fines should be presented to the watchman, whose vigilance in this respect will thereby be greatly increased. Reliable automatic devices are always preferable to means depending on human agency, and for this purpose the "automatic electric low water alarm" is highly recommended; this is a device which sets an electric bell in the superintendent's office into operation as soon as one quarter of the contents of a bucket evaporates, and continues to ring until the bucket is filled. Buckets should be of iron, not wood, as wooden buckets, when they are dry or partially empty, shrink and become leaky. They should be well covered, first, with a zinc coating, which is generally called galvanizing, and then with good tar or asphaltum paint, put on hot, which will cause buckets to last much longer than they otherwise would. The word "Fire" should be painted on them with large letters—red is to be preferred as that color can be seen best—so that one may know their purpose and readily discover them in case of emergency. All factories should have trained bucket brigades, as it is not easy to use a bucket properly. It seems an easy matter to pour water upon a burning substance; but when we consider that, in the majority of cases, it is impossible to reach the point of fire, and

that, therefore, water must be thrown from a distance, it is self-evident that it is quite an art to throw the contents of a bucket on the spot necessary, without spilling or wasting the greater part of it. In order to make a bucket brigade efficient, they should practice once or twice a week. Every room which contains buckets should contain large casks with wide opened tops, so that the buckets may be readily refilled. I frequently find casks with the top so small that it is almost impossible to introduce the bucket into the opening and procure water, and it would be utterly impossible, in case of fire, when people are frightened to a craze. It is a notable fact that more than twice as many fires are extinguished by buckets than by any other means. The importance of having factory buildings properly equipped with them is therefore obvious.

PUMPS.

The oldest and first-described fire pump is that described in the Spiritalia of Hero, 150 years B. C.

[A slide showing this pump was projected on the screen.]

One of the best and strongest pumps, in places where water power is used, is the French Rotary. Its chief merit lies in its great strength. Its operation is due to the displacement of water between the teeth of two coarse gears. Its construction is very simple. There are no weak and small parts which break; no valves which require constant attention, while it is very durable and wears out slowly. It should take its supply from the flume, and should be about 18 inches above the water level, so that it may not be flooded. Driving belts should not be used, as a fire will soon destroy these. In the same way bevel gears are objectionable, because they are apt to slide, causing the various parts to stick, and the pump to become worthless when most needed. Friction gears, when the pump is strongly erected, are perhaps best; although, when the heat becomes great, they become warped, but stand longer than any other arrangement.

[A number of slides, showing the construction and the general arrangement of water-power pumps, were then shown.]

STEAM FIRE PUMPS.

The pre-requisite conditions in choosing steam fire pumps are, that they should be simple, strong, and, which is included in the foregoing, there should be as few small and weak parts as possible, as these are

apt to get out of order and break. All fire pumps should be supplied with a relief valve (which relieves excessive pressure), as when the pump is running at full head, hose is frequently bursted, and as it is often impossible to reach the pump during the fire, the hose with which it is connected becomes worthless when most needed, as was the case at the fire of a large chemical works a short time ago. A fire pump should be placed where it is least exposed to fires; preferably outside in a fire-proof compartment, so that the attendant may have access to the pump to the very last, and the pump may still work even if the entire remainder of the property be destroyed.

[A number of slides, showing the general construction of the various fire pumps, were projected on the screen.]

VERTICAL PIPES.

I do not think much of the outside vertical, or, as they are sometimes called, Palmieri pipes; which are run along the outside of buildings, extending to the roof; the intention being that, in case of fire, the Fire Department will attach the engine to the lower end and the hose to the connection on the roof. It has, however, been demonstrated by experience, that, with few exceptions, as in the case of a few very high buildings, firemen prefer to carry their hose on their ladders to the top of the building, and such pipes are, therefore, of little value in case of fire, as firemen will not use them.

Inside stand-pipes or vertical pipes, on the contrary, are of great importance. These should be connected with tanks of large capacity or with good force pumps, so that strong pressures may be obtained in them at all times, as the pressures of the City Water Departments, especially on higher stories, are inadequate. We frequently, in our Philadelphia Specials, find vertical pipes connected with the City water supply, which, on being tested, will throw a stream of not more than ten or fifteen feet. Care should be taken to place all vertical pipes away from exposed positions. These pipes should never be placed along walls exposed to the wind, as, in winter, the cold will cause the water to freeze and burst the pipes, the arrangement becoming worthless. They should always be placed in positions which will be least apt to be destroyed by fire, and which, in case of fire, will be least exposed to flames and smoke. Fire-proof stairway houses are well adapted for this purpose, as firemen in them are able to fight the fire until the last moment, as they know they still have a fire-proof way of retreat, and can, at any moment, protect themselves by

closing the fire doors which lead into the stairway house. Vterical pipes should be of ample size, so that the requisite amount of water can be drawn from them. A good pressure in it is the pre-requisite of an efficient stand-pipe.

[A number of slides were shown, explaining the various modes of erecting stand-pipes.]

HYDRANTS.

In the ordinary hydrant, the water is at all times contained in it.

[This was shown and explained by a number of stereopticon views.]

In order to keep the water from forcing into the upper portion of the hydrant, which is apt to deteriorate it, causing parts to corrode, several devices have been constructed, such as the Matthews', and the Chapman hydrants, in which the water is turned on by valves in the lower end of the hydrants, which is, therefore, eliminated from the upper parts of the plugs. A similar construction is used for our ordinary fire plugs. The name, "fire plug," is derived from an English expression, and in its original appellation is entirely correct. An English plug is a device for reaching water, in the following manner: The main water supply, running along the street, is punched with holes at various parts, and these are closed by wooden plugs, tightly driven in. On top of these a box is fitted, which is filled with manure or straw, in order to keep the water from freezing. In case of fire, the fire department must first remove the manure or straw, knock out the wooden plug, and make connection with the opening, and pump the water from the pipe. Plugs of this kind are still used, to a certain extent!

It was through the admirable labors of the father of a Vice President of this Institute, Mr. Frederick Graeff, that plugs were first invented and introduced in our city and throughout the United States, and their introduction has now become general in every civilized country in the world.

[A number of slides, illustrating the various hydrants, was shown.]

VALVES.

Only straight valves should be used for turning on water. Mr. Woodbury states he found, in a number of experiments made by him at Holyoke some time ago, that a two-inch globe valve reduced the pressure from 89 to 40 pounds per square inch.

[This was further explained by means of slides projected on the screen.]

A valve or hydrant which is not water-tight, on being closed by hand, without great effort, is to be deprecated, and should never be employed, as it is liable to break, on account of the excessive strains applied to certain parts when it is opened and closed. Jenkins' and Chapman's straightway valves can be recommended.

[These were shown and explained by means of slides.]

It is absolutely necessary that all valves in a factory should open in one direction only. I have frequently found that even the same factory contained valves which opened in different directions. It is no wonder, therefore, that mistakes are made, especially when people are highly excited as in case of fire. In order to overcome this difficulty, valves should be labelled with an arrow and the word "*open*" painted on it conspicuously, so that any person, even unacquainted with the valve, may be enabled to open it properly. It is an unfortunate coincidence that even among mechanics and engineers, the words right-hand and left-hand valves do not have the same significance. In some parts of the country the word "right-hand" signifies the motion of the hands of a clock, while in other districts, as used even by some persons in the same district, the term signifies the opposite. It would be well if conventions would take the matter in hand and settle the term once for all.

Chapman's gate, which was introduced some time ago, is a very good one, as it can be opened or shut by one turn of the hand to every inch diameter of the gate. For example, a six-inch gate is shut or opened by six turns of the hand wheel, etc. As further advantages for the gate are claimed, "that it opens in the natural manner, advancing stem, full opening, with the utmost quickness of motion, without water hammer."

[Several gates and methods of construction were then projected on the screen.]

HOSE.

I prefer unlined linen hose for inside use even to more expensive kinds. Woodbury states that twelve samples from different manufacturers, weighing from three and three quarters to four ounces per foot, burst when new, at pressures of from 420 to 650 pounds per square inch. Several experiments made by myself, with similar hose,

gave even better results, bursting at pressures, between 415 and 670 pounds per square inch; but it is only proper to state that the best samples were furnished me for the express purpose of testing, and may, therefore, have been of extra strength.

In order that a hose shall remain in good condition, it must be kept dry, and should not be wound on reels. A hose, on a reel, after some time, on being unreeled, assumes a winding form similar to an Archimedean screw, and when run off in a hurry, is apt to *kink*, and cut off the supply of water at times when it is most needed. Hose should be kept on a pin, and should be laid on with looping ends, as loose twine is frequently kept on a nail..

[The manner was then shown by a sketch on the board.]

The pin should be protected with a round, broad saddle or back, so that the hose may not crack, as it will when hanging on too sharp an edge. If hung properly on a pin, it may be drawn off without the slighest danger of *kinking*.

It is absolutely necessary that uniform couplings should be introduced throughout, not only for regular fire departments, but also for factories. The old screw coupling labors under the serious disadvantage that if the hose is not permanently attached to the hydrant, in the event of fire and excitement, it is difficult to attach the hose properly. For this purpose Jones' patent coupling, which is now used in most of our public fire departments is excellent, as the hose may be quickly attached, even by excited persons. Care must, however, even in this simple coupling, be taken to press the joints together tightly, as complaints are often made by incompetent persons, that the joints leak. If they are put together properly, no leakage will occur. In the ordinary Jones' coupling the rubber strip, which forms the tight joint, extends a short distance into the coupling, and therefore, to a certain extent, retards the flow of the water and reduces the pressure, it has been claimed by some, as much as 20 per cent. Clay's coupling, in which the rubber strip does not protrude into the opening, or water way, is an important improvement, as it does not retard the velocity or pressure of the stream. A great advantage with the Jones' coupling is that with an increase of pressure, up to about 300 pounds to the square inch, the joints become tighter, and are, therefore, less liable to leak.

NOZZLES.

I still prefer the old leather nozzle, with a metal tip, to the long

metal nozzles, which are now much used. A leather nozzle may be bent in all directions which one of metal cannot be, and as in fighting fire it is very frequently necessary that the fireman shall stand behind a projection, and direct the stream by bending the nozzle without exposing much of his body to the heat and flames, the importance of short metal nozzles or leather nozzles is evident. Morse's monitor nozzle is an important invention, as by simply turning a crank the nozzle may be turned in any position and held there. The so-called "spray" nozzle is a new and valuable invention, as it is frequently impossible for firemen to see on entering a burning building, on account of smoke, sometimes created by insignificant fires, which it is impossible to detect for some time, on account of the smoke generated. The spray nozzle produces a fine spray, which precipitates the smoke around it, giving the firemen an opportunity to see and follow up the fire.

Drip couplings are good for places in which the hose is attached to hydrants at all times. They consist of couplings with small openings or slots in the bottom, so that any contained water or water created by the leakage of valves, will not reach the hose (and which would deteriorate it), but will escape through the slot before reaching the same.

Pressure at Hydrant. Pounds per sq. inch.	Discharge per minute. Gallons.	Distance reached by jet.	
		Horizontal feet.	Vertical feet.
15	84	54	26
20	98	62	35
25	112	72	45
30	122	80	52
35	132	88	60
40	140	96	67
45	149	103	75
50	157	111	80
55	165	118	88
60	172	125	93
65	180	132	101
70	186	139	106
75	193	145	111
80	199	150	116
85	205	156	121

The above table, taken from the excellent work of Mr. Geo. A. Ellis, serves as a basis for estimating the diameter of distributing mains, for the passage of water through them, and is found for 100 feet of rubber hose and one inch smooth nozzle:

[A number of lantern projections illustrated the various nozzles.]

TANKS.

Tanks should be of large size, even larger than is usually thought to be sufficient. They should be provided with an overflow valve, and the contents should not be allowed to freeze. This can be prevented by passing an exhaust steam pipe through the tank, or by mixing the water with salt, which will at the same time prevent the formation of organic slimes, which are objectionable. The tank should be in a position least exposed to the cold north winds. An alarm valve should be introduced in the tank, which gives an alarm, either by whistle or bell, whenever the water falls below a certain height in the tank. A better arrangement is an automatic electric alarm, which can be put in connection with the office of the superintendent, and gives the alarm there whenever the water falls below a certain height in the tank, being at the same time a tell-tale on the engineer in charge of the pump. Tanks should always be placed on the strongest part of a building, and on that part which will be apt to stand longest in case of fire. A fire-proof stair-way house, well sheltered from the flames of the surrounding buildings, is an excellent position.

SPRINKLERS.

For some years past mills have been provided with perforated sprinkler pipes, which extend through the mill lengthwise, and are perforated with numerous holes, one-tenth of an inch in diameter and from eight to ten inches apart. When a fire occurs, the water is turned on by a valve outside of the building, water rushing into the pipes, and being discharged through the openings. The great objection which is found to this system in practice is that the water is not confined to those spots only at which the fire occurs, but is distributed over the entire premises provided with such sprinkler pipes, and frequently it was found that the damage done by the water was inestimably greater than that which would have been done by the fire.

Another great objection to it, is, that it requires human help in order

to turn it on, and all who have had experience in *fire technology* know of how little this is to be relied upon in case of fire.

To overcome these various objections, automatic sprinklers were invented several years ago, the earliest forms being turned on by means of levers with weights attached to them, which were held in position by strings, which, on burning through, released the lever and set the sprinklers in operation. At present, automatic sprinklers consist of a system of pipes, which extend near the ceiling, and the water is released, by valves attached to the pipes, by the heat created by the fire. The valves are kept closed by means of fusible solder, which melts at a temperature of 150°F. or over. The heat which arises from the fire melts the solder joint of the valves immediately over the place where the fire occurs, the water is expelled and is delivered just where it it is needed at the time, and not thrown over the entire premises, as was the case with the former sprinklers.

Automatic sprinklers are divided into two great classes, (1) *sealed sprinklers*, such as the Rose, Bishop, Burritt, Parmelee, etc.; and (2) the *sensitive*, such as the Neracher, Kane Bros., Brown & Hall, Buell, Burritt, Grinnell, etc.

Automatic sprinklers have now been in use for about twelve years, and a series of tests made by Mr. Woodbury shows that the fusible solder has not deteriorated in that time, and still possesses all its valuable properties. It was formerly thought that the solder would in the course of time, through corrosion (oxidation and pressure), become worthless, which these tests seem to disprove. The effectiveness of automatic sprinklers is shown by the fact that out of 110 fires in factories in which they were introduced, and of which the amount of damage was accurately determined, for 67 or 60·9 per cent. no damage was claimed; for 12 or 10·9 per cent. the damage done was less than $250; for 8 or 7·2 per cent. the amount of loss was between $250 and $500; for 11 or 9·9 per cent. between $500 and $1,000; for 12 and 10·9 per cent. between $1,000 and $20,000.

I consider automatic sprinklers to be specially valuable in those parts of factories in which finely divided organic substances or dusts are created, as, for instance, in the picker and card rooms of textile mills, in flour mills, malt mills and so on, as the water projected from the ceilings precipitates the dust, and therefore removes one of the most dangerous sources and causes of fire, and prevents the fire from extending further by means of the ignitible dust.

[The various sprinklers which have been tried and found effective were then shown and explained by means of slides projected on the screen.]

By a series of tests made by Professor Morton, President of the Stevens' Institute, for the New York Board of Underwriters, it was shown that the tank which supplies the sprinklers should in every case be at least ten feet above all pipes; and the following table shows the amount of water which is used in fifteen minutes for pipes of the following diameters, to which the number of sprinklers indicated are attached:

Tank, ten feet above all pipes.

Diameter of Pipe.	Number of Sprinklers Supplied.	Gallons running for fifteen minutes.
¾ inch	2	212
1 "	4	424
1¼ "	5	530
1½ "	9	954
2 "	16	1,696
2½ "	25	2,550
3 "	36	3,816
3½ "	49	5,194
4 "	64	6,784
5 "	100	10,600
6 "	144	15,264

STEAM JETS.

Live steam is one of the best agents we possess for extinguishing fires in small inclosed compartments. All small rooms, such as picker and drying rooms, should be supplied with ample sized steam jets. In order to make steam jets effective they should be turned on from the outside, the valves being located in some secure position, as the first impulse of every one, in case of fire, is to run out; when reason returns, a person is more apt to turn on a valve from the outside than he would be to enter the burning room and turn the valve. But, in order to make a steam jet absolutely effective, it should be automatic. For this purpose I invented the following device: On the steam supply pipe a ring is tightly fitted, to which is attached a rod, which, on its

end, is formed into a fork-like projection. On top of this fork a bar is placed, to which a rope, impregnated with substances which will cause it to burn rapidly when ignited, is attached; and the two sections of the rope are held together by means of a fusible solder joint. This rope serves to hold in place a lever to which a weight is attached. This lever is in connection with a valve. I use for this purpose a spring valve, constructed by the Bellfield Valve Company, which will not corrode, and which works easily and well in all cases. To the small rod, which rests on the open fork, a rod is attached, which passes through a small slot or pipe in the wall to the outside, and to it a convenient handle is attached. Now, let us suppose that a fire occurs in a picker room, and that, as is generally the case, the employés run out. Should one of them be cool headed enough, he would go to the outside, pull the handle, and thereby draw the bar, which rests loosely on the open fork, from the fork; the lever would drop and open the steam into the room. But, let us suppose that the employé has not the proper amount of coolness, and runs away without turning on the steam from the outside. Then the temperature will rise to 160°F., the temperature at which the fusible solder joint will melt and separate (the solder joint may be fixed for any temperature by altering the composition and proportions of the ingredients of the solder); the lever will be released, as in the former case, and the steam turned on. Let us, however, suppose that through some unforseen accident the solder joint would not work, then we still have as a third means the extremely inflammable rope, which would soon be ignited, and burn through, thus causing the valve to be turned on. We therefore have three alternatives, one of which would undoubtedly come into play.

In all steam jets, be they automatic or otherwise, valves should be used which can be turned on readily. I have frequently found valves so tightly corroded and stuck fast that they were worthless in case of fire.

EXTINGUISHERS.

Extinguishers contain water which is of value on account of the carbonic acid gas which it contains, which replaces the air, the burning body being at the same time incrusted with a layer of salts.

Carbonic acid is an excellent extinguishing agent in any form. I suppose you all have seen the experiment of extinguishing a number of candles placed in a trough, by pouring carbonic acid gas in one end and allowing it to flow through.

One of our large soda water establishments has extinguished several small fires in their building and neighborhood by means of the carbonic acid contained in their soda water appliances. A druggist extinguished a small fire of benzine, which had ignited in his store, by a bucketful of soda water, which he sensibly drew from his fountain and poured upon it, instead of using ordinary water, which would have been of no avail.

Extinguishers, in the proper sense of the term, as first used, consist of apparatuses containing gas, which in case of fire is liberated, displacing the air and thereby extinguishing the fire. The apparatus of Cartier consists of a cylinder of sheet-iron which is tested to a pressure of eighteen atmospheres. To both ends are attached bottoms of sheet steel, and by means of a specially constructed filling pipe in the upper end, water and bi-carbonate of sodium are poured and the pipe tightly closed, and when used tartaric acid is injected by a special device, which causes the formation of carbonic acid gas and sodium tartrate. These are partially dissolved by the water, and the gas produces a pressure of from four to seven atmospheres on the contained liquid, which, when the cock of the nozzle is opened, produces a strong stream. Shaeffer and Budenberg use the same substances under a pressure of ten atmospheres.

Instead of the expensive tartaric acid, Zabel and Dick first substituted sulphuric acid. In Dick's apparatus the sulphuric acid is contained in a separate glass, which, in case of fire, is broken and then reacts on the bi-carbonate of soda. In Zabel's apparatus the sulphuric acid is contained in a glass cylinder, which is turned upside down in case of fire, and the cover, thereby opening, allows the acid to flow out and mix with the salts; thus producing the gas.

Similar to these are the apparatuses of Masnata, who releases carbonic acid gas with sulphuric acid and the carbonates of different elements; and the apparatuses of Baragwanath and Van Wisker.

Among the efficient American extinguishers may be mentioned the Harkness Pneumatic Extinguisher. A new extinguisher called "The Climax," is before you. In this, sodium bi-carbonate and oxalic acid is used. The extinguisher is charged with water, and the dry material is placed in two receptacles above it. When used, the dry material is dropped into the water by relieving the bottoms of the receptacles which are attached by hinges; carbonic acid gas is generated and oxalate of sodium formed, the charged water being ejected by

means of a small pump attached to the apparatus. This is an excellent extinguisher, while used on the floor, as it may be frequently refilled, fresh substances being added, and the pumping continued; but it cannot be used on ladders, as is necessary in reaching ignited substances on high walls or ceilings.

Platt's extinguisher, which has been kindly loaned me for this evening, has been used with great success for many years. Its great value consists in its simplicity, as the most ignorant workmen can be readily taught to use it. It is put into operation by merely turning the valve handle as far to the left as possible, and turning the extinguisher upside down. This firm also manufactures small extinguishers, which can readily be carried on the back, and which can be used on ladders for reaching substances which cannot be reached by a stream from the ground. These extinguishers were employed in the Electrical Exhibition.

In selecting fire extinguishers we must, as in choosing all other machinery, take those which are simplest and least apt to get out of order, and those which contain substances, and arrangements by which the metal of the apparatus is not corroded, (as many are put into the market which will last but a few years, on account of the corrosive nature and method of placing the ingredients.)

Of late, so-called hand grenades have been used. These devices, though highly ornamental, I do not approve. The extinguishing material is contained in bottles, which must be broken in order to cause the extinguishing liquid to be spread over the flames. It is exceedingly difficult to break the bottles over a fire, by taking two bottles, as is generally advised, and breaking them over the point of danger; while we frequently find the bottles, which are strongly made, are not broken by throwing them into inaccessible places, or into such materials as burning yarn, raw stock, waste, etc. The joke of a prominent underwriter when he first saw them is perhaps not out of place, who said that in case of fire one would be apt to look for a corkscrew to remove the cork in the bottle before putting out the fire. The wire racks in which some grenades are placed are valuable additions. These consist of wire baskets so arranged that when the grenades are removed from them, a fire alarm is given.

EXTINGUISHING POWDERS.

Bucher's extinguishing powder partially rarefies the air, by heating the atmosphere, and also withdraws air in enclosed spaces, producing sulphurous acid, which tends to smother the fire. According to Heeren, the value and extinguishing results of burning di-sulphide of carbon does not consist in the absorption of oxygen from the air, and the effects of burning Bucher's powder are not produced by the resulting gases replacing the air, but, he believes, that the gases which are thus caused, consisting largely of sulphurous and carbonic acid gas, having a higher specific gravity than air, prevent all draught or circulation around burning substances, and that, therefore, air cannot reach them and supply the oxygen necessary for combustion. Liquified sulphurous acid is one of the best agents for extinguishing fire.

Bucher's powder, as prepared by Wittstein, contains 60 parts of saltpetre, 36 parts of sulphur and 4 parts of charcoal. Schweizer prepares the powder with the following composition: Saltpetre, 58·53 parts; sulphur, 36·33 parts; charcoal, 3·14 parts; sand, 75 parts, and oxide of iron, 1·25 parts. Heeren prepares Bucher's powder in the following manner: Saltpetre, 63·73 parts; sulphur, 28·93 parts; charcoal, 3·80 parts, and oxide of iron, 3·54 parts.

The ingredients are not powdered quite as finely as for the manufacture of gunpowder. They are then mixed and placed in small packages of pasteboard, so tightly packed that only a very sharp instrument can separate the particles. The composition can readily be ignited and burns (without exploding) with a strong white flame and strong penetrating odor and smoke. Out of every pound, 4·82 cubic feet of gas are produced, consisting of 2·36 cubic feet of sulphurous acid, 1·10 cubic feet of carbonic acid, and 1·36 cubic feet of nitrogen. According to Bucher, about one pound of the material should be used for every 240 cubic feet of space. In case of fire, the powder is thrown into the fire, whereby the results above described will be produced.

These powders are only of value in small enclosed rooms, without many ventilating openings, and has practically proved valueless in places exposed to great draughts. One great objection to it is that it is extremely dangerous to life, as several cases of severe accidents have occurred in Europe. It has been of great value in drying rooms, where substances coated or impregnated with petroleum compounds are dried; Dorn reports for instance, a case in which a severe fire in the drying room of an oil cloth factory was extinguished by it.

The extinguishing composition of Zeisler consists of 60 parts saltpetre, 36 parts sulphur, and 4 parts charcoal and lime. The mass, after being mixed, is compressed into cartridges by means of a hydraulic press, and several of them are connected by a hermetically enclosed easily ignitable fuse.

Gruneberg's composition consists of 20 parts potassium chloride, 50 parts potassium saltpetre, 50 parts sulphur, 10 parts rosin and 1 part magnesium di-oxide, tightly packed in the form of cartridges.

Johnstone's powder consists of equal parts of potassium chloride, rosin, potassium saltpetre and black oxide of manganese, moistened with water-glass, and then pressed into briquettes, a number of which are shipped in one box, being connected by a fuse which can readily be ignited and thus ignite the mass. The box being suspended near the ceiling.

OTHER MEANS.

Other means for extinguishing fire which have been used are di-sulphide of carbon, liquified sulphurous acid, the gaseous products from under the boiler, water-glass, salt, magnesium chloride, sulphate of aluminium, ammonia gas, borax, sodium phosphate, Glauber salts, soda, etc.

Burning fats, rosins, pitch, etc., can be successfully extinguished by placing wire gauze of very fine mesh over the burning mass. The reason for this, which explains also the efficiency of the Davy safety lamp, is, that flames are not transmitted through wire gauze, as the wire being a good conductor, conducts away the heat, preventing the flames from passing through it.

Sand is a very good agent for extinguishing fires originating in pitch, tar, petroleum and its products; as in this case water will be of little value, while sand, when piled upon burning substances, cuts off the supply of oxygen from the air, causing the flames to be extinguished.

FIRE BRIGADES.

Fire brigades were in use among the ancients. Thus we find under Augustus Cæsar, A. U. C. 732, that the Romans had a fire brigade of 600 freedmen.

Organized fire brigades in factories, should be drilled at least once a week. Every man should have his special duty assigned him and know exactly what to do in case of fire; only these men should be

allowed to take part in extinguishing fires; strict rules should be promulgated, that every one not belonging to the fire brigade must remove from the premises as soon as the fire alarm is given, thus giving the firemen room to work. The brigade should be drilled at a different hour weekly, for if they be always drilled at the same time, they will be prepared for the event; will go through their drill at this time in good manner, but when a fire starts at another time they may be excited and slow to get to work. For this reason it is necessary that the chief of the brigade give the fire signal at different times every week, and thus get the department on duty at times when they do not expect it. He will thereby, accustom his people to get to work rapidly at all times, and as they do not, at the time when the alarm is first struck, know if it is merely an alarm or an actual fire, in the course of time get over the excitement which is generally incidental to such an occurrence. It is absolutely necessary, that the chief shall insist on all occasions that his men get to work immediately. If he allows slovenly practice, he will have the same state of affairs in case of fire.

WATCHMEN.

A good watchman is of great advantage in a mill, but in order to effectively control him, watch-clocks or time detectors, as they are more frequently called, should be introduced, as a watchman, without a watch-clock, in the majority of cases, is unreliable. It is a standing joke of the Patrol that the first thing they have to do in arriving at a fire is to save the watchman, as he is almost invariably sound asleep and would burn to death.

[Various time detectors were shown on the screen, such as the stationary clock, to which a button lever is attached, which must be pushed at required times, either hourly or half hourly, as the rounds may be, and will the next morning, from the perforations on a time card, show the superintendent if the watch has been properly carried on. The Buerk's time detector which consists of a clock, which the watchman carries with him, while the keys are fastened. The marks on the card next morning show whether the watchman has made his rounds.]

Special care must be taken to have the keys or stations provided in all dangerous places where fires are likely to originate, so as to keep them under constant supervision.

A clock gains in value by simplicity, and the manner in which it is protected from being tampered with by watchmen as it is frequently to their interest to conceal breaches of discipline by so doing.

For this reason an electric time detector is an excellent arrangement it consists of buttons placed at the various stations, the watchman, in pressing these, gives a signal impression on a time card in a clock in the superintendent's office. It is very difficult for the watchman to tamper with this apparatus as his only means is to cut the wire, which in well managed establishments would cause his immediate dismissal.

[Various electric watch-clocks were then thrown on the screen and explained.]

FIRE ALARMS.

The first fire alarms used were either large bells, gongs, or whistles which, by their peculiar sound, would make known that a fire had originated. The ordinary steam whistle is an excellent arrangement. This consists of a hollow hemisphere against which the steam is blown from a valve, the metal is set in vibration, imparts this motion to the contained and surrounding atmosphere, setting this also in vibration, thus producing a sound. Where steam whistles are used as fire alarms it is necessary that these should be very loud and have a shrill peculiar sound, different from all others in the neighborhood, so that persons may at once recognize it.

Automatic fire alarms have been introduced for some time. One of the oldest is that of Joseph Smith, first introduced in 1802, which was set in operation by means of a cord, which being burnt through released a lever in connection with a steam whistle or a bell.

Another apparatus used was a wire extending over a mercury receptacle, connected with a lever, which it held in place. When the temperature rose, the mercury contained in the receptacle touched the wire, amalgamated the same, which caused the tensile strain on the wire to part it, relieve the lever and cause an alarm. These devices were never of much practical value.

Of late the so-called thermostats have been introduced. These are of various construction; some consisting of strips of different metals, tightly fastened together, which, by their unequal expansion, bend, thereby forming contact with a metal strip, which closes an electric circuit, causing an alarm to be struck at the fire station.

Another consists of a bulb containing mercury, into the bottom of which a wire is melted, and in the upper end a wire which does not touch the mercury, is hermetically sealed. When the temperature

increases, the mercury in the column rises and touches the upper wire, forming contact, closes the circuit, and gives the alarm at the station.

Another very ingenious device is that of Fein of Stuttgart, which consists of an arrangement held in place by means of a spring, the spring in its turn being held in place by a fusible cylinder. The temperature rises, destroys the fusible cylinder, the spring is released, and contact is made, an electric circuit formed giving the alarm.

[A number of these devices were then thrown on the screen and explained.]

HEAVY RAINS AND VOLCANIC ERUPTIONS.—M. Guy accounts for the heavy rains in the spring of 1884 by the condensation of vapor on the particles of volcanic dust which gave the brilliant twilights of the preceding autumn and winter. He cites in confirmation of his opinion the conclusion of Aitken's memoir in the transactions of the Royal Society of Edinburg for 1880 81. The eruptions of Skaptar-Jokul in Iceland in the beginning of May, 1873, of the new volcano in the Gulf of Sicily in the early part of July, 1831, of Cotopaxi in 1856, and of Vesuvius in 1862 were followed by brilliant sunsets and also by heavy rains.—*Comptes Rendus*, June 23, 1884. C.

SOLDERING ALUMINUM.—The use of aluminium is greatly limited by the difficulty of soldering it to itself or to other metals. M. Bourbouze begins by tinning the pieces which are to be joined; but, instead of using pure tin, he employs alloys of tin with other metals, giving preference to those of tin and aluminium. For articles which are to be worked after soldering, a good alloy is composed of 45 parts of tin and 10 alumnium, which is malleable enough for hammering, punching and turning. When there is to be no working, the soldering alloy will require less aluminium and it can be applied in the usual manner by a common soldering iron.—*Comptes Rendus*, June 16, 1884. C.

LUNAR AUREOLE.—On the 4th of July, 1884, at 9 h. 30 m. P. M., Tacchini observed that the moon was very red and surrounded by a reddish halo which had a breadth of about a lunar diameter; the tint was nearly that of copper. The phenomenon was observed by one of his assistants and by other persons. A similar appearance was presented on the following evening, but the tint was much feebler. On the 6th the sky was cloudy, and subsequently there was no repetition of the phenomenon. During the three nights mentioned there was great humidity, the air being nearly saturated through the night while during the day the humidity fell to ·40.—*Comptes Rendus*, July 15, 1884. C.

The ELECTRICAL DETERMINATION of the VELOCITY of PROJECTILES.

By Prof. Edwin J. Houston.

Various electrical contrivances have been devised for the accurate determination of the velocity of projectiles. These may be divided into three classes, viz.: the Ballistic Pendulum, invented by Robins in 1740; the Gun Pendulum, employed by Count Rumford, 1781; and an Electrical Method, first suggested by Wheatstone in 1840.

An excellent display of such appliances was made at the International Electrical Exhibition of the Franklin Institute, by the United States Ordnance Department, under the charge of Captain Otto Ernst Michaelis, of the Frankford Arsenal.

In the ballistic pendulum the velocity of a projectile is calculated by means of the deflection which it produces in a freely moving pendulum, the bob of which is of a size sufficient to receive the impact of the projectile. The ball, penetrating the heavy pendulum bob, imparts to it a velocity which is calculated from the arc described by the pendulum, and the time in which the whole mass vibrates. A projection below the bob is employed to mark the extent of the deflection of the pendulum.

The gun pendulum depends for its action on the measurement of the arc of recoil of a gun, suspended in a horizontal position, so as to freely vibrate.

The electrical method consists essentially in causing the projectile in its flight to successively rupture two targets formed of wire screens. Each of these screens is placed in the circuit of a voltaic battery and an electro-magnet. Each electro-magnet has a pencil so attached to its armature, that its point is held near, but not in contact with the surface of a revolving cylinder. As the ball pierces the wire screens it breaks the circuit of the electro-magnets, and permits a spring to move the armatures from the magnet poles, and so permit the pencil to make a mark on the surface of the revolving cylinder. The distance between the screens being known, as well as the velocity of rotation of the cylinder, the distance between the two markings will readily give the velocity of the ball between the two screens. This velocity, which will of course be the mean velocity, is appreciably the actual velocity of the ball at the middle point of the distance between the two screens.

Wheatstone's electrical method is preferable to either of the preceding. It is more accurate, and requires less bulky apparatus.

The use of electro-magnets in the above method introduces an error in the time required for the spring to come into action and press the pencil point against the surface of the revolving cylinder. This difficulty is removed by a method first suggested by Professor Henry, in 1843.

According to Henry's method, the electro-magnet is replaced by an induction coil. Each wire screen forms part of the circuit of the primary wire in an induction coil. On its rupture by the projectile, the induced current in the secondary coil causes a spark that punctures the paper on the surface of the revolving cylinder. This method of marking the time of rupture is now generally adopted.

Various forms of apparatus have been devised for measuring the minute interval of time required for a projectile to successively rupture the two wire screens. One class of such appliances will be found in what may be termed electro-ballistic apparatus. This form of apparatus was devised by Navez, in 1849.

In electro-ballistic apparatus, the projectile, instead of striking the pendulum, and imparting to it a given velocity, simply releases a pendulum that is ready to fall under the influence of gravity. This release is effected when the projectile pierces the first wire screen. If, then, we can ascertain the exact position of the pendulum when the projectile pierces the second wire screen, and hence the distance it has fallen through, the time of flight between the wires can be readily calculated by determining the time required for the pendulum to fall freely through such distance.

The pendulum is held in position by an electro-magnet, in whose circuit the first screen is included. The passage of the ball through the first screen, therefore, permits the pendulum to begin its fall. On the passage of the ball through the second screen, the pendulum, or a detachable portion thereof, is arrested by the action of a powerful electro-magnet.

In Vignotti's Electro-Ballistic machine, a wire is placed over the gun so that the pendulum is released at the moment of firing. Marks are made on a paper placed on a graduated circle, by the sparks of induction coils, whose primaries are included in the circuit of the two wire screens. While the pendulum is falling, therefore, two marks are made on the paper, as the projectile successively ruptures the two

screens. The time required for the flight of the projectile between the two screens is determined by ascertaining the time required for the pendulum to fall from its zero point to each of the two marks. The difference of these times will be the time of the projectile's flight.

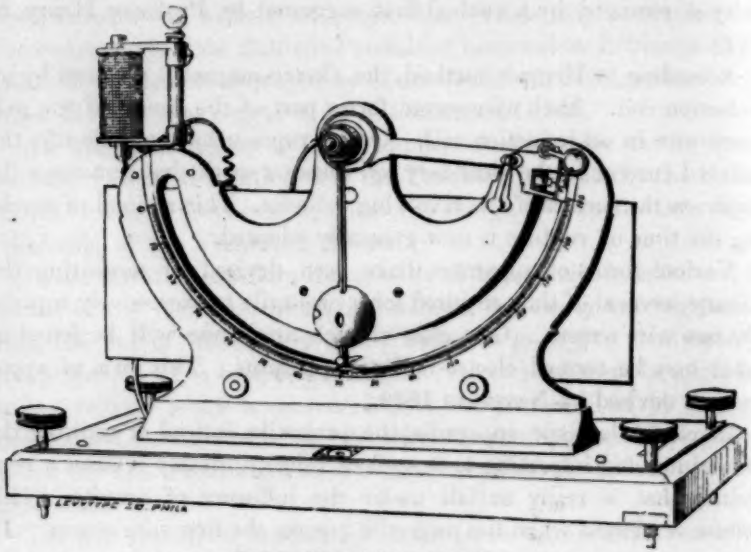


FIG. 1.—Vignotti's Apparatus.

This form of electro-ballistic apparatus is shown in Fig. 1. It consists of a graduated limb, provided with an annular slot through which a sheet of paper, moistened with a solution of potassium ferrocyanide, receives a spark from an induction coil. A brass plate is shown in the figure as placed back of the graduated limb and its annular slot. A pendulum swings before the limb with its axis suitably insulated therefrom. A fork is provided at the extreme end of the limb to catch the bob of the pendulum and limit its motion to a single swing. An electro-magnet, placed to the left of the limb is provided to hold the pendulum at the zero point of the graduated limb.

A wire placed over the muzzle of the gun is ruptured at the moment of firing, and breaking the current of this electro-magnet, permits the pendulum to fall.

One terminal each of the secondary wires of two Ruhmkorff coils is connected in series. The free terminal of one coil, the negative, is connected with the pendulum, and the free terminal of the other coil,

the positive, to the metallic plate back of the graduated limb. The primary of the first coil is inserted in the circuit of the first wire screen, and that of the second coil in the circuit of the second screen.

At the moment of firing, the pendulum is released. When the pro jectile pierces the first screen, the rupture of the primary of the first induction coil induces a current, which passing through the secondaries of both coils punctures the paper and produces therein a colored mark; similarly, the rupture of the second screen produces a mark which shows the position of the pendulum at this moment.

From these data, as we have already explained, the time of flight of the ball may be readily calculated.

The Vignotti apparatus was improved at the Frankford Arsenal, under the direction of Colonel T. T. S. Laidley, Ordnance Corps, in the following particulars, viz.: the error of reading, due to the small arc described by the pendulum, was, to a great extent, eliminated by releasing the pendulum before firing. This was effected by means of a falling weight, which in its descent ruptured an electric circuit including an electro-magnet, which upheld the pendulum. The chemical paper was replaced by a soot-covered silver arc. These improvements were used on the apparatus shown at the exhibition.

In Benton's Electric Ballistic Pendulum, or Velocimeter, the successive ruptures of the wire screens permit the free fall of two pendulums suspended in front of a graduated circle, with their axes in a line passing through the centre of the circle and perpendicular to the plane of the arc; or, in other words, two concentric pendulums, one swinging in front of the other, are held in a horizontal position at opposite extremities of the graduated arc, by the attraction of electro-magnets for a piece of soft iron attached to the lower extremity of each pendulum bob. These electro-magnets are included in the circuit of two separate batteries with the two wire screens or targets. As the projectile successively ruptures the targets, the pendulums are released and move over the graduated circle in opposite directions, and are caused to mechanically record the point of meeting on the graduated circle.

Benton's Electro-Ballistic Pendulum, or Velocimeter, is shown in Fig. 2. The semicircle is graduated 90° in each direction from the zero point, which is at the lowest point of the arc. The electro-magnets are placed at the extremities of the graduated circle in the positions shown. The bob of the outer pendulum is made adjustable so as to readily synchronize the two pendulums. At the lower extremity of

the inner pendulum is a movable point that projects towards the graduated circle. The outer pendulum is provided with a blunt steel point that strikes the movable point on the inner pendulum as the two pendulums pass each other, and thus makes a mark on a sheet of paper attached to the graduated circle.

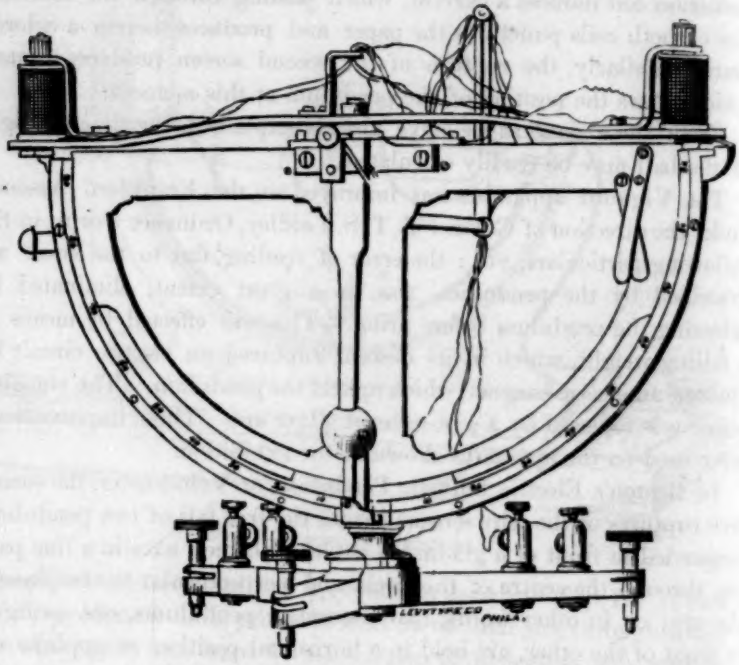


FIG 2.—Benton's Electro-Ballistic Pendulum.

Should both pendulums be simultaneously released, they will meet at the zero or lowest point of the arc, and will therefore make a mark on the paper at this point; but if one is released after the other, the difference in the times of release is readily determined from the position of the mark on the graduated scale.

FIG. 3.—Key For Electro-Ballistic Pendulum.

In order to assure the same ease and consequent rapidity of release

of the two pendulums by the electro-magnets, it is necessary that the two batteries charging them be of exactly the same strength. This is ascertained by means of a special key shown in figure 3, which simultaneously breaks the circuits of the two batteries. If the two pendulums meet at the zero point of the graduated arc the two batteries are of the same strength.

As it is impracticable to maintain the two batteries at exactly the same strength, the electro-magnets are provided with movable, adjustable cores. In this manner an adjustment is readily obtained by means of which the recording of the meeting point of the two pendulums at the zero of the scale, when simultaneously released, is effected.

An improved device for the marking point is shown in Fig. 4.

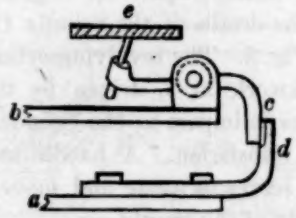


FIG. 4.—Marking Point of Benton's Velocimeter.

The bent arm *d*, is attached to the outer pendulum *a*. The lever *c*, is attached to the inner pendulum. As the two pendulums meet, the arm *d*, strikes the lever *c*, and pressing its marking point at the outer end against an ivory arc *e*, records thereon the point of meeting.

In the Schultz Chronoscope, a carefully tuned fork is caused to mark a waved line on the blackened surface of a revolving and sliding cylinder. This waved line serves as a scale of actual time; for, if the rate of the forks' vibration, that is the number of complete vibrations, or to and fro motions it makes in each second, be known, then clearly each wave on the blackened surface will have been made in a known time.

Suppose, for example, that Fig. 5 represents the waved or sinuous line traced on the blackened surface by the fork, then while the fork is making one complete swing, to and fro, it will trace the waved line between 0, and 1, or between 1, and 2. Consequently the cylinder has moved through the distance of the straight line between 0, and 1, while the fork has completed one to and fro motion. If therefore the fork

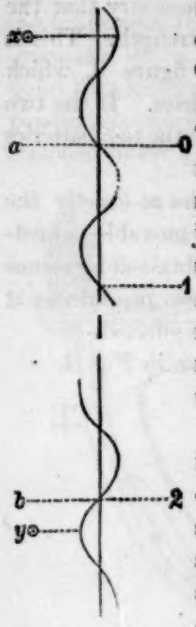


FIG. 5.—Sinuous or Waved Line Traced on Blackened Surface by Forks.

makes 23 complete vibrations per second, the length of this line represents the $\frac{1}{23}$ part of a second of time. Or, if the fork make 512 vibrations per second, the line 01 would represent the $\frac{1}{512}$ part of a second. The use of tuning forks evidently permits very minute intervals of time to be readily and accurately measured. Their use also permits the velocity of a projectile to be measured at a sufficient number of points throughout its flight, to enable the law of its movements through the air to be studied, for it is evident from the extent of surface that can be given to the revolving cylinder that the number of targets, and their distance apart can be greatly varied.

The details of the Schultz Chronoscope are shown in Fig. 5. The revolving cylinder is seen at 1. The clockwork at 2, driven by the suspended weight, serves to impart to the cylinder a motion of rotation and translation. A handle attached to the driving axis serves to rotate and move the cylinder independently of the weight.

The tuning fork 4, is kept in constant vibration by the action of the electro-magnets placed as shown. A flexible point, attached to one tine of the fork can be caused to touch the surface of the cylinder when so desired. The interrupter 6, makes and breaks the circuits of the battery energizing the electro-magnets that keep the fork in constant vibration. This interrupter acts in the usual manner.

The mercury interrupter has been applied by the inventor as best serving to ensure constancy and continuousness of the forks' vibration. This interrupter is, however, extremely sensitive and difficult to adjust. Lieutenant Russel, of the Ordnance Corps, has disposed with the interrupter and caused the fork to do its own "rheotoming."

The well known sensitiveness of a tuning fork to hygrometric changes in the atmosphere necessitates, in the determination of very minute intervals, that its previously ascertained rate of vibration be discarded and its rate determined at the same time as the exact record. For this purpose the Froment pendulum accompanying the apparatus is not sufficiently delicate. Messrs. Bond, of Boston, have made for the Ordnance Corps a seconds break-circuit chronometer, which, by the

insulation of the breaking screw, gives a half-seconds break, entirely independent of the chronometer train.

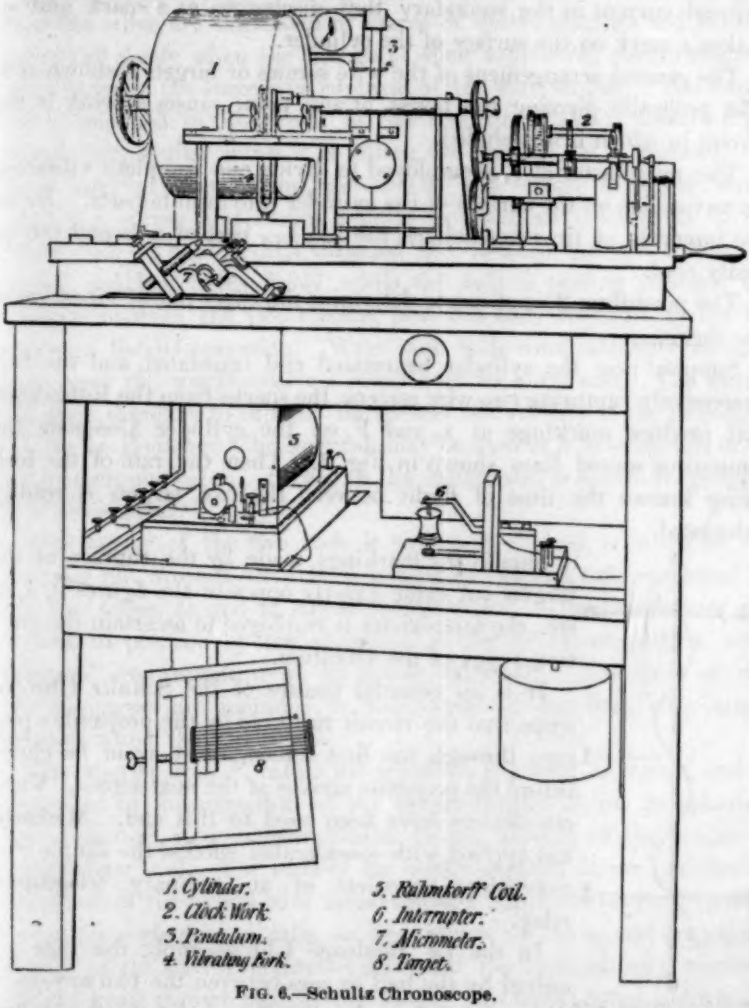


FIG. 6.—Schultz Chronoscope.

Michaelis has simultaneously applied two break-circuit chronometers, by means of two induction coils, for determining the true rate of the fork. The mean number of vibrations per second were

By first chronometer	248·2575
By second "	248·2276

The Ruhmkorff coil 5, has its primary included in the circuit of one of the wire targets, and, at the moment of its rupture, produces an induced current in the secondary that discharges as a spark and so makes a mark on the surface of the cylinder.

The general arrangement of the wire screws or targets is shown at 8. The projectile piercing the target at any point causes a break in the circuit in which it is included.

The micrometer at 7, is employed to divide one complete vibration or waved line on the surface of the cylinder into minute parts. By its use intervals of time as small as the $\frac{1}{500,000}$ part of a second can be easily read.

The pendulum 3, is of use to determine the exact rate of vibration of the fork.

Suppose now the cylinder be rotated and translated, and the ball successively rupturing two wire screens, the sparks from the Ruhmkorff coil produce markings at x, and F, on the cylinder alongside the sinuous or waved lines shown in Fig. 7. Then the rate of the fork being known the time of flight between the two targets is readily calculated.

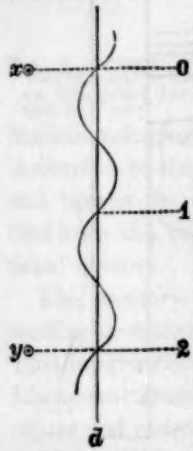


FIG. 7.—Curved line produced by the Schultz Chronoscope.

Should the markings made by the rupture of the targets not come exactly opposite the figures 0, 1, 2, etc., the micrometer is employed to ascertain the fractional part of the vibration.

It is an essential feature of the Schultz Chronoscope that the circuit ruptured by the projectile's passage through the first screen, must again be closed before the projectile arrives at the next screen. Various devices have been used to this end. Michaelis has applied with considerable success the simple and convenient expedient of an ordinary telegraphic relay.

In the Le Boulengé Chronograph, the time required by the ball to pass between the two screens, is deduced by observing the distance of the free fall of a heavy body during such time. This instrument is therefore different from the electro-ballistic pendulum apparatus already described, in that the movements of all pendulums is necessarily constrained by the fact of their suspension, or quoting Michaelis in his

description of this instrument, it "reduces the pendulum to its bob and allows it to fall freely."

In the Le Boulengé Chronograph two rods, one of which is longer than the other, are suspended by means of electro-magnets and permitted to fall freely when the circuits of their supporting electro-magnets are broken by the successive ruptures of the wire targets. The longer rod is included in the circuit of the first target and is therefore released first, so that while it is falling the shorter rod is released. A brief interval after falling, the shorter rod strikes a trigger which releases a spring and causes a knife to make an indentation in the larger rod. There is thus obtained the distance through which the longer rod has fallen freely while the ball is passing through the distance between the two screens, plus the time required by the instrument for its operation. Were both rods simultaneously released the longer rod would receive a mark near its lower end. The nearer the mark therefore to this end the greater the velocity of the projectile.

The Le Boulengé Chronograph may be used as a velocimeter, or as a micro-chronometer. In Fig. 8 the instrument is shown in position as a velocimeter.

The longer of the two rods is shown at *C*, and is called by the inventor the *chronometer*. It is a long cylindrical rod, enveloped by two zinc tubes, *D*, and *E*, called the *recorders*. The chronometer rod is held in position by the attraction of the electro-magnet *A*, on a spherical iron armature at its upper extremity. The coils of this electro-magnet are included in the circuit of the first wire target through which the ball passes.

The shorter rod, *E*, called the *registrar*, is placed as shown, and is supported by the attraction of the electro-magnet *B*, for its spherical iron armature, in a manner similar to the support of the longer or chronometer rod. The coils of the electro-magnet *B*, are included in the circuit of the second wire target through which the projectile passes. When the registrar rod falls, on the rupture of the second target, the free end of the lever *I*, is thereby depressed, the main spring is released, and the knife thrown against the falling chronometer rod indents the upper recorder. A hollow tube, *L*, intended for the reception of the registrar rod *F*, is adjusted so that the rod falls without touching it.

The details of the indenting apparatus are shown in Fig. 10. The lever *I*, pivoted at *T*, releases the main spring *H*, and permits the circular knife *G*, to indent the upper recorder.

In order to insure the free fall of the rods the electro-magnets are preferably weak, though of course strong enough to support the rods

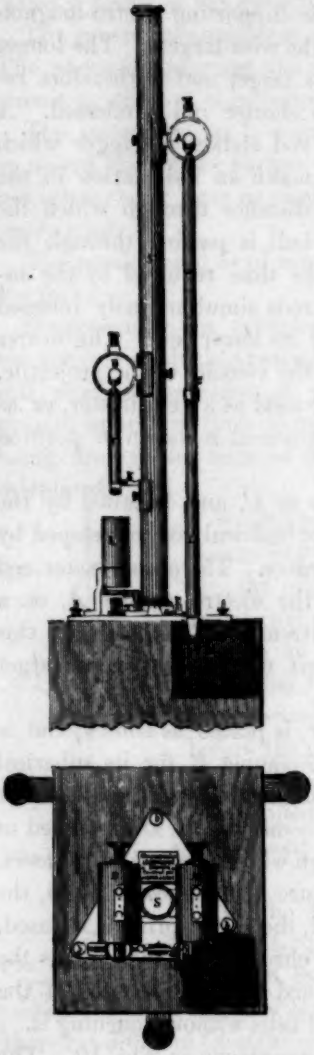


FIG. 8.—Le Boulengé Chronograph in Position as a Velocimeter.

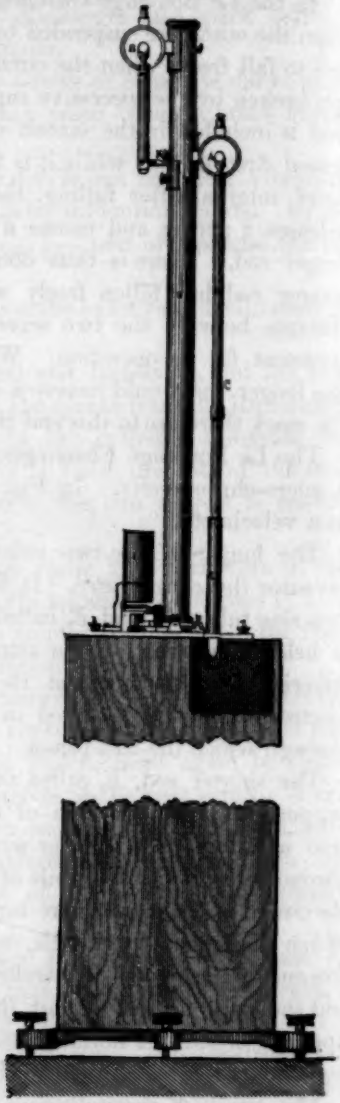


FIG. 9.—The Le Boulengé Chronograph in position for use as a micro-chronometer.

with certainty. In this manner the errors due to the residual mag-

netism, which result in a short interval, elapsing between the fall of the rods and the rupture of the screws, is diminished.

When the Le Boulengé Chronograph is employed as a velocimeter, as in Fig. 8. and the distance between the two wire targets is comparatively great, the chronometer rod receives an indentation near the top, or at the moment of time when it is falling with its maximum velocity, and therefore minute differences in time, are recorded by comparatively great differences in height. When, however, the interval is exceedingly small, this arrangement of the apparatus has the disadvantage that the record of the fall of the registrar rod is received by the chronometer rod near its lower end, where the velocity of fall is small. A different arrangement is therefore desirable when it is wished to employ the apparatus as a micro-chronometer. This is effected by a very simple readjustment of the instrument. This readjustment is shown in Fig. 9. where the instrument is represented in position for use as micro-chronometer.

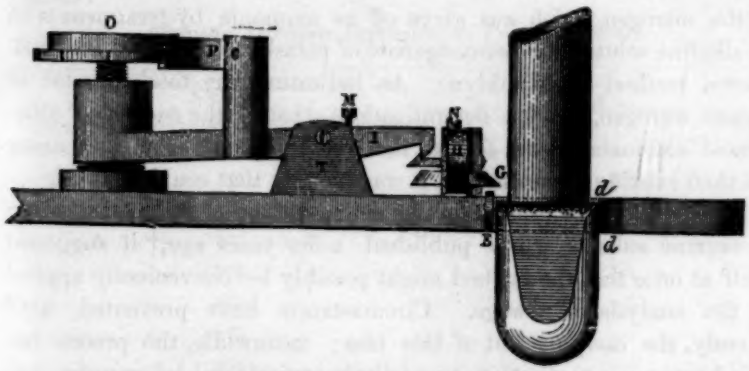


FIG. 10.—Indenting Apparatus.

In this figure it will be observed that the registrar rod with its stop and supporting electro-magnet *B*, are removed to the upper part of the instrument. They are now included in the circuit of the wire target that is broken first. The longer rod therefore begins to fall after the first has been falling and when *B*, strikes the lever *I*, at the lower part of the apparatus, it causes the indent to be made on the upper recorder, or when the longer rod has its greatest velocity. By means of this ingenious modification, very minute intervals of time are easily and accurately measured.

In the preparation of the above descriptions the author has consulted

the work by Benêt, on "Electro-Ballistic machines and the Schultz Chronoscope," and the work by Michaelis, on "The Le Boulengé Chronograph." He is indebted to these works for the accompanying cuts.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, Nov. 29, 1884.

CONTRIBUTIONS TO OUR KNOWLEDGE OF SEWAGE.

BY WM. RIPLEY NICHOLS AND C. R. ALLEN.

In the year 1872, one of us had occasion to report* the results of the chemical examination of a considerable number of samples of the sewage of Boston and of Worcester, Mass. The examinations then made included the determination of the nitrogen existing as ammonia or in the form of ammoniacal salts (tabulated as free ammonia), and of the nitrogen which was given off as ammonia by treatment with an alkaline solution of permanganate of potash, according to the well-known method of Wanklyn. As indicating the total amount of organic nitrogen, this last determination—that of the so-called "albuminoid ammonia"—was felt at the time to be inadequate, but under the then existing circumstances it was the best that could be done.

When Kjeldahl's process for the determination of the total nitrogen in organic substances was published a few years ago,† it suggested itself at once that the method might possibly be conveniently applied to the analysis of sewage. Circumstances have prevented, until recently, the carrying out of this idea; meanwhile, the process has found extensive application, especially in agricultural laboratories, and has been used in the analysis of certain kinds of fertilizers. It is possible that it may have elsewhere been applied to the examination of sewage; if so, we have failed to meet with notice of such application, which we find to be quite practicable and to give satisfactory results.

In order to familarize ourselves with the process and, at the same time, to become satisfied of its substantial accuracy, determinations of

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* Fourth Annual Report of the State Board of Health of Massachusetts. Boston, 1873. Pp. 65-81.

† *Fresenius Zeitschrift*, xxii (1883), p. 366; *Chemical News*, xlviii (1883), p. 101.

the total nitrogen were made in sulph-urea, in dried and powdered horse dung, and in dried and powdered human excrement, the amount of nitrogen being checked either by theory or by an absolute determination according to Dumas' method. The results were as follows:

	I. Kjeldahl's method.	II. Dumas' method.	III. Theory.
Sulph-urea	36·80 per cent.	.....	36·84
Horse dung. 1	3·16 "	3·28	.....
" 2	3·12 "	.....	.....
Excrement	6·20 "	6·08	.....

In order to satisfy ourselves as to the constancy of the results obtained in a number of determinations made on the same sample of actual sewage, a sample was procured and analyzed with the following results:

Organic Nitrogen Expressed as Parts in 100,000.

Kjeldahl (after deducting nitrogen as free ammonia).	Dumas.
3·75	3·60
3·50	.....
3·75	.....
3·70	.....
3·75	.....
3·75	.....
3·80	.....

It thus appears that the process gives uniform results, and that these results are sufficiently accurate for the purpose. It has the advantage of requiring only the ordinary apparatus used in water analysis, as generally conducted in this country, and of avoiding a dry combustion, which, in the simplest form, is more or less troublesome, especially where a liquid has to be evaporated, and the solid residue transferred from the evaporating dish.

There is little doubt that the coming decade will see in this country a considerable application of the method of disposing of sewage by irrigation, and it seems to us that Kjeldahl's process will afford a ready

means of determining the amount of that important constituent—the combined nitrogen. The process, as we have used it with sewage is as follows:

From 25 to 50 cubic centimeters of sewage are introduced into a small flask, preferably flat bottomed, made acid with sulphuric acid and evaporated to dryness on a water-bath. This is best and most rapidly accomplished by drawing through the flask a somewhat rapid current of air which has been freed from moisture and ammonia by bubbling through strong sulphuric acid. We have satisfied ourselves that the loss of "free ammonia" by this treatment is inappreciable so that the residue contains the total combined nitrogen* of the sewage. This residue is treated in the flask with 5 cubic centimeters of fuming sulphuric acid which is run in from a glass-stoppered burette. The flask is placed on a piece of wire-gauze over a small gas-flame and heated until a light yellowish-brown liquid is obtained. With sewage this result is sometimes reached in half an hour; usually from one to two hours are required. Permanganate of potash is then added to complete the oxidation, a few crystals being sufficient.†

The contents of the flask are then washed into the distilling apparatus with about 500 cc. of pure distilled water, enough caustic potash is added to give an alkaline reaction, and the nitrogen, which is now all in the form of ammonia, is distilled off in the usual way. The distillate is made up to 250 cc. and aliquot portions are nesslerized as in water analysis. As the sulphuric acid usually contains a trace of nitrogenous compounds, a blank experiment determines a slight correction to be applied.

The process as just given may be modified by evaporating the sewage without first acidulating with sulphuric acid. The evaporated water may be condensed and the free ammonia determined therein and an approximate determination of the total solids may be made by using a tared flask. We prefer, however, to proceed as indicated above and to make a separate determination of free ammonia, with which may be coupled, if desired, a determination of the so-called albuminoid ammonia.

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* The nitrogen which exists in the sewage as nitrites and nitrates is too small to be of practical importance although there is usually a trace.

† For fuller details, see Kjeldahl's original paper, referred to above.

BOSTON SEWAGE.

Since the examinations of sewage made in 1872, the Boston system of sewerage has undergone an entire change. Instead of being discharged from short sewers emptying at intervals along the water-front, the sewage is now collected into one encircling sewer, carried by means of a tunnel to Moon Island and allowed to flow into the outer harbor on an ebb tide.

We have examined a number of samples taken from the pumping station at City Point where the sewage is lifted in order that it may flow through the tunnel to Moon Island. The sewage was received as a rule in a fresh condition; the heavier suspended particles were allowed to subside and no attempt was made to determine their amount. In fact, the determination of suspended matters in small samples is of little value and a more practical idea of their amount could be obtained on a large scale by estimating the amount deposited in the settling-tanks. The following table contains the results of the examination of various samples of sewage from the pumping station. It will be noticed that the samples taken at different times vary very much from each other. The large amount of total solids and chlorine are said to be due to the fact that a considerable quantity of sea-water is used in certain manufactories for cooling purposes and to the infiltration of salt water into the sewers which are below the tide level.

NITROGEN AS UREA.

The rapidity with which urea is converted into carbonate of ammonia and water in the presence of the urea ferment which is probably always present in sewage, would prevent its existence in stale sewage, but as the Boston sewage reaches the point from which our samples were taken in a fresh condition, we might expect to discover some of this substance still unchanged.

The evidence that urea was present in several samples which were tested is as follows: Two portions of 50 cc. each were boiled in small flasks to expel the free ammonia and to kill any of the ferment present, and the necks of the flasks then stopped with cotton wool. When the contents had become cool one of the flasks was infected by dipping a glass rod first into a fermenting solution of urea, or into stale sewage and then into the boiled sample. The two samples were allowed to stand side by side for several days, and then examined for free

Examination of Boston Sewage.

[Results expressed in parts in 100,000.]

Number.	Date of Collection.	Ammonia	Albuminoid Ammonia	Total Nitrogen, reckoned as Nitrogen.	Total Nitrogen, reckoned as Ammonia	Total Solids.	Chlorine.	Chlorine reckoned as common salt.	Phosphoric Acid. (P_2O_5.)
1	1885. May 12, 7.30 P. M.	2·80	0·27	2·80	3·40	592	275	453	0·480
2	13, 8.20 A. M.	3·18	0·44	3·46	4·20	548	258	425	0·006
3	13, 7.20 P. M.	3·42	1·15	5·76	7·00	254	82	135	0·6?2
4	14, 7.20 A. M.	1·32	0·35	1·81	2·20	570	247	407	0·704
5*	15, 1.00 A. M.	1·29	0·87	4·63	5·62	482	135	219	1·343
6*	15, 8.15 A. M.	1·59	0·25	6·00	7·30	416	194	320	0·512
7	15, 4.00 P. M.	3·08	0·55	3,76	4·57	358	145	239	0·192
8	16, 7.30 A. M.	0·95	0·55	2·14	2·60	630	311	513	0·288
9	17, 4.25 P. M.	5·08	5·96	14·53	17·65	551	215	354	7·035
10	18, 8.00 A. M.	6·23	5·84	13·82	16·78	528	?	?	6·490
11	24, 7.50 P. M.	11·94	3·32	17·15	20·82	178	59	97	3·325
12	23, 12.40 A. M.	?	2·62	4·32	5·30	378	178	293	0·992
13	26, 12 hour day average†	5·71	4·22	11·32	13·75	460	177	292	4·893
14	27, 12 " " " †	5·71	3·31	9·55	11·60	640	288	475	6·188
15	28–29, 24 " average‡	3·13	5·49	9·82	11·93	588	240	396	4·702
	1872. Average of 33 day samples‖	2·72	0·73	.....	.....	59	19	31	1·69¶
	" " 4 night "	1·33	0·23	.....	.....	17	4·5	7·4	.....

* Samples 5 and 6 contained a good deal of storm water. † Samples taken every four hours. ‡ Samples taken every two hours.
‖ Samples from sewers near the water front, which evidently contained much sea-water, were not included in these averages.
¶ Average of 19 samples.

ammonia is a similar fashion. In one case the flask which had not been impregnated was free from ammonia, generally, however, a small amount of ammonia had developed itself,* in all cases the impregnated flasks showed a much greater amount of ammonia than was contained in the companion flasks. This certainly points to the presence of urea or some similar fermentable nitrogenous compound in the sewage as it reaches City Point.

In conclusion we desire to acknowledge our indebtedness to the Department of Improved Sewage for facilities in collecting samples, especially to Mr. Barnes, at Chester Park, and to Mr. M. H. Holmes, at the pumping station.

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* Probably the initial boiling had not expelled the whole of the free ammonia.

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E. HILTEBRAND, *Librarian.*

USE OF THE OPTICAL TELEGRAPH.—The optical telegraph which has been successfully established between the Isle of Bourbon and Mauritius is likely to prove of great value to commerce by its storm warnings. Bourbon has only open bays where ships run great risks during cyclones if they do not weigh anchor soon enough to flee before the tempest. Mauritius which has an excellent harbor, is situated on the route which the cyclone traverses before reaching Bourbon. By the optic telegraph information can be sent to the latter island in time to enable all the vessels to take such precautions as are needful.—*Les Mondes*, Sept. 11, 1884. C.